DIET OF BOTTLENOSE DOLPHINS *TURSIOPS TRUNCATUS* IN THE NORTHWEST FLORIDA PANHANDLE AND FORAGING BEHAVIOR NEAR SAVANNAH, GEORGIA

By

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Abstract

The foraging ecology of bottlenose dolphins *Tursiops truncatus* in the Northwest Florida Panhandle and estuaries in northern Georgia was determined using diet analysis and behavioral surveys. Stomach content analysis was completed on bottlenose dolphins (N = 25) that stranded in the Northwest Florida Panhandle from November 2006 to March 2009. The most abundant prey species were spot *Leiostomus xanthurus* (20.4%), squid (10.9%), pinfish *Lagodon rhombiodes* (10.3%), and Atlantic croaker *Micropogonias undulatus* (8.5%). Dolphins that stranded during months with a red tide *Karenia brevis* bloom consumed more pinfish, and spot; whereas dolphins that stranded in non-bloom months consumed more squid, Atlantic croaker, and silver perch *Bairdiella chrysoura*. Differences in diet were also identified for dolphins that stranded inside bays/sound and dolphin that stranded outside of bays along the coast, and male and female dolphins. Surveys were conducted from south of the Savannah River to north of Ossabaw Sound in Georgia where foraging behaviors were classified. Multivariate Generalized Additive Models were used to test correlations of behaviors to dolphin group size, depth, salinity, temperature, creek width, and tide. Sightings with headstands ($p = 0.009$), hard stops ($p = 0.019$), chasing ($p = 0.004$), mudbank whacking ($p < 0.001$),

herding/circling ($p = 0.024$), and strand feeding ($p = 0.006$) were correlated with shallow water or small creeks. Sightings with kerplunking ($p = 0.031$), mudbank whacking ($p = 0.001$), strand feeding ($p = 0.003$), and herding/circling ($p = 0.026$) were significantly correlated with low tide. The results of the Savannah, Georgia study were the first to characterize foraging behaviors in this area and demonstrate how bottlenose dolphins utilize the salt marsh estuary in terms of foraging. Studies like these are important to determine how dolphins forage efficiently and to provide background information on diet and foraging behavior for use in monitoring future impacts to dolphins in the Northwest Florida Panhandle and near Savannah, Georgia.

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CHAPTER 1

Introduction

The common bottlenose dolphin *Tursiops truncatus* is found along coastal and offshore waters making this species one of the best studied marine mammals in the southeast United States (Wells and Scott, 2008). Some of the biggest threats to bottlenose dolphins include biotoxins and interactions with humans (NOAA, 1994; NOAA, 2004; Flewelling et al., 2005; Read, 2008). These threats are linked to foraging ecology as bottlenose dolphins forage in association with humans and can ingest contaminated prey (Flewelling et al., 2005; Reynolds et al., 2005). To understand the extent of threats, information on bottlenose dolphin foraging ecology is necessary (Reynolds et al., 2005).

The most common theory on diet selection and foraging behavior is the optimal foraging theory (Pyke, 1984). In this theory, a predator will forage on prey items for which the time to search and handle these items will be less than the energy gained (Emlen, 1966; MacArthur and Pianka, 1966). In addition, predators will become more selective of prey items or specialize in foraging in environments where prey are abundant (Emlen, 1966; MacArthur and Pianka, 1966). Testing this theory is difficult on mobile prey and in environments where the abundance and distribution of prey are constantly changing (Sih and Christensen, 2001). Further difficulties arise when this theory is applied to the study of cetaceans because they only spend limited time at the surface

where they can be observed. However, the foraging aspects of bottlenose dolphins have been studied through stomach content analysis, behavioral studies, stable isotopes, and fatty acid signatures (Barros and Odell, 1990; Nowacek, 2002; Gannon and Waples, 2004; Torres and Read, 2009; Tollit et al., 2010).

Sciaenidae (croakers) and other bottom dwelling fish are the most important prey species of bottlenose dolphins in terms of frequency, abundance, and biomass of prey identified from dolphin stomachs (Barros and Odell, 1990; Barros and Wells, 1998; Gannon and Waples, 2004). The reason Sciaenidae are abundant in the diet may be explained by the passive listening hypothesis (Barros and Odell, 1990; Barros, 1993; Barros and Wells, 1998; Gannon and Waples, 2004; Berens McCabe et al., 2010). Dolphins may listen to find soniferous prey, such as Sciaenidae, rather than use echolocation, which could conserve energy (Barros, 1993; Gannon et al., 2005; Berens McCabe et al., 2010). Dolphins in the wild were found to change swimming direction towards sounds of soniferous fish, reinforcing the passive listening hypothesis (Gannon et al., 2005).

The diet of bottlenose dolphins in the southeast United States can vary by location and habitat (Barros and Odell, 1990; Barros and Wells, 1998; Gannon and Waples, 2004). In North Carolina, bottlenose dolphins that stranded in estuaries mainly consumed Atlantic croaker *Micropogonias undulatus*, and those stranded along ocean beaches (coasts) consumed mostly weakfish *Cynoscion regalis* (Gannon and Waples, 2004). This is likely due to differences in density and life stages of fish between bays and coasts (Ayvazian et al., 1992; Hoese and Moore, 1998; Nelson, 2002). In addition to differences in prey species, the sizes of prey can be different between dolphins that

stranded inside estuaries from dolphins that stranded along ocean beaches. Many juvenile species of fish are found in estuaries (Hoese and Moore, 1998; Nelson, 2002). Gannon and Waples (2004) found that dolphins that stranded on ocean beaches consumed larger weakfish and spot than the dolphins that stranded inside the estuary.

Differences in the diversity of diet exist between dolphins from the Gulf of Mexico and eastern coast of Florida (Barros and Odell, 1990). These differences may relate to differences in prey available for both locations (Hoese and Moore, 1998) or differences in foraging, for instance foraging in association with shrimp vessels. By-catch from shrimp vessels are a source of food for bottlenose dolphins in the Gulf of Mexico (Fertl and Leatherwood, 1997). Thirty-two percent of bottlenose dolphin stomachs from the western and northern Gulf of Mexico contained shrimp, fish, and squid, whereas only 4.5% of dolphin stomachs from the eastern coast of Florida had all three prey types (Barros and Odell, 1990). The bottlenose dolphins from the western and northern Gulf of Mexico may have had a higher diversity in diet due to feeding on the by-catch of shrimp vessels (Barros and Odell, 1990).

Bottlenose dolphins are not equally distributed within an estuary, but tend to congregate and are more frequently observed at specific locations (Würsig and Würsig, 1979; Ingram and Rogan, 2002; Mendes et al., 2002). These locations are often related to habitat characteristics and environmental variables such as tidal cycles (Ingram and Rogan, 2002; Mendes et al., 2002). (Ingram and Rogan, 2002). Concurrently, prey species have habitat preferences, and prey distributions are related to habitat characteristics and environmental variables (Moser and Gerry, 1989; Peterson and Turner, 1994; Shervette et al., 2007).

A variety of foraging behaviors have been described for bottlenose dolphins and some of these behaviors involve single animals while others involve groups of dolphins working together. Examples of individual foraging behaviors of bottlenose dolphins include but are not limited to kerplunking, fish whacking, and mud plume feeding (Wells et al., 1987; Connor et al., 2000a; Lewis and Schroeder, 2003). To catch schooling prey, dolphins often work together. One type of cooperative foraging among bottlenose dolphins includes strand feeding. This behavior occurs in Georgia and South Carolina where dolphins create a pressure wave that temporarily strands fish and themselves on a mudbank during low tide (Hoese, 1971; Rigley et al., 1981; Petricig, 1995). There may be other unknown foraging behaviors of bottlenose dolphins throughout the estuaries near Savannah, Georgia. The correlations of strand feeding and other potential foraging behaviors with environmental variables have yet to be determined.

Bottlenose dolphins in the southeast United States also forage in association with human activities (Leatherwood, 1975; NOAA, 1994; Fertl and Leatherwood, 1997). Such activities include: dolphins feeding on fish by-catch from shrimp trawlers; dolphins feeding on catch, bait, and discards of recreational fisherman; and humans illegally feeding wild dolphins (Leatherwood, 1975; NOAA 1994; Powell and Wells, 2011). Dolphins that feed in association with human activities risk injury from entanglement, lacerations from boat propellers, altered natural behavior, and inappropriate or contaminated food (NOAA, 1994; Samuels and Bejder, 2004).

The prey and foraging behavior of bottlenose dolphins along the Northwest Florida Panhandle and Georgia have yet to be thoroughly studied. However, in both areas, biotoxins and human impacts have caused concern for the health of local

bottlenose dolphin populations (NOAA, 1994; NOAA, 2004; Pulster et al., 2009). In the Northwest Florida Panhandle, NMFS has declared three Unusual Mortality Events (UME) due to above-average bottlenose dolphin mortalities between 1999 to 2006 (NOAA, 2004; unpublished data Gaydos et al.[1]). All three events were determined to be attributed to harmful neurotoxins called brevetoxins, which are produced by the red tide organism *Karenia brevis* (NOAA, 2004; unpublished data Gaydos et al.[1]). Brevetoxins can accumulate in food webs, which may explain the delayed mortalities observed in these events (Flewelling et al., 2005; Naar et al., 2007; Fire et al., 2007). *K. brevis* blooms may also reduced the amount of available prey (Gannon et al., 2009). Declines in fish density and species richness have been attributed to *K. brevis* blooms (Gannon et al., 2009).

The purpose of this thesis was to identify the foraging ecology of bottlenose dolphins in the Northwest Florida Panhandle and near Savannah, Georgia. The most common prey species of bottlenose dolphins from the Northwest Florida Panhandle were identified by investigating stomach contents of stranded dolphins. Differences between diets of dolphins that stranded during a *K. brevis* bloom and diets of dolphins that stranded in the absence of the bloom were compared. Due to a small sample size of stomachs from dolphins in Georgia, the foraging behaviors of dolphins were documented instead. The foraging behaviors of bottlenose dolphins in the estuaries near Savannah, Georgia were categorized, and correlations between foraging behaviors and

[1] Gaydos, J.K., N.B. Barros, G.D. Bossart, S.R. Bowen, K. Evans, R. Ewing, M.L. Fleetwood, L. Flewelling, R. Hardy, C. Heil, C. Johnson, W. Jones, J. Kucklick, J. Landsberg, J. Litz, T.A. Leighfield, C. Lockyer, B. Mase, W. Noke, P. Rosel, D.S. Rotstein, T. Rowles, L. Schwacke, T. Spradlin, M. Stolen, M.J. Twiner, and F.M. Van Dolah. In preparation. Brevetoxin-associated bottlenose dolphin (*Tursiops truncatus*) Unusual Mortality Events in the Florida Panhandle: 1999-2000, 2004, and 2005 - 2006. NOAA Technical Memorandum NMFS-OPR-XX.

environmental variables were made. Strand feeding behavior was further investigated and discussed.

CHAPTER 2

Stomach contents of bottlenose dolphins *Tursiops truncatus* from the Northwest Florida Panhandle in relation to a *Karenia brevis* bloom

Abstract

Bottlenose dolphins *Tursiops truncatus* in the Northwest Florida Panhandle are threatened by *Karenia brevis* blooms which produce brevetoxins that bioaccumulate in fish. The purpose of this study was to identify the diet of bottlenose dolphins from the Northwest Florida Panhandle and determine if diet changed during a *K. brevis* bloom. Stomachs (N = 25) were collected from stranded bottlenose dolphins from November 2006 to March 2009 and contents were identified to the lowest taxonomic level possible. Differences in prey species abundance were significant between bloom and non-bloom strandings ($p > 0.01$). Dolphins that stranded during bloom months consumed more pinfish *Lagodon rhomboides* (11.5%) and spot *Leiostomus xanthurus* (39.7%); whereas dolphins that stranded in non-bloom months consumed more Loliginidae (squid, 32.3%) and Atlantic croaker *Micropogonias undulatus* (11.4%). Dolphins that stranded in the bay consumed more spot (25.1%) and pinfish (14.2%), whereas dolphins that stranded along the coast consumed more silver perch *Bairdiella chrysoura* (10.1%) and Penaeidae (shrimp, 7.2%). Female dolphins consumed more Arridae (catfish, 7.0%), pigfish *Orthopristis chrysoptera* (7.1%), and spot (28.5%); whereas males consumed more Atlantic croaker (16.0%) and silver perch (11.1%). Differences in diet may expose some bottlenose dolphins in the Northwest Florida Panhandle to higher levels of brevetoxins.

This research highlights the importance of consistent sample collection in order to understand the effects of harmful algal blooms on marine mammals.

Introduction

Bottlenose dolphins *Tursiops truncatus* in the Gulf of Mexico are repeatedly threatened by *Karenia brevis,* which produces a suite of harmful neurotoxins called brevetoxins (Gunter et al., 1948; Baden and Mende, 1982; NOAA, 2004; Naar et al., 2007). Three bottlenose dolphin Unusual Mortality Events (UMEs) have occurred in the Northwest Florida Panhandle from 1999-2006 involving 348 bottlenose dolphin mortalities (NOAA, 2004; unpublished data Gaydos et al[1]). UMEs are defined as any mass live or dead strandings that are unexpected, demand an immediate response, and involve a significant die-off of any marine mammal population (MMPA 1992, Section 404). The first UME occurred from August 1999 to May 2000 when a total of 152 bottlenose dolphins were found dead along the Northwest Florida Panhandle (unpublished data Gaydos et al.[1]). The beginning of the event had the majority of the mortalities recovered from the St. Joseph Bay (unpublished data Gaydos et al.[1], Figure 2.1). From there, the mortalities proceeded west along the coast to the Choctawhatchee Bay. A total of 70.4% (107/152) dolphins from this event were found inside the bays, sounds, and estuaries of the Northwest Florida Panhandle (NOAA, 2004). In 2004,

[1] Gaydos, J.K., N.B. Barros, G.D. Bossart, S.R. Bowen, K. Evans, R. Ewing, M.L. Fleetwood, L. Flewelling, R. Hardy, C. Heil, C. Johnson, W. Jones, J. Kucklick, J. Landsberg, J. Litz, T.A. Leighfield, C. Lockyer, B. Mase, W. Noke, P. Rosel, D.S. Rotstein, T. Rowles, L. Schwacke, T. Spradlin, M. Stolen, M.J. Twiner, and F.M. Van Dolah. In preparation. Brevetoxin-associated bottlenose dolphin (*Tursiops truncatus*) Unusual Mortality Events in the Florida Panhandle: 1999-2000, 2004, and 2005 - 2006. NOAA Technical Memorandum NMFS-OPR-XX.

another UME was declared in the Northwest Florida Panhandle; however, this event only lasted 6 weeks and remained isolated in St. Joseph Bay (NOAA, 2004; unpublished data Gaydos et al.[1]). A total of 67 out of 107 mortalities (62.6%) were recovered from inside St. Joseph Bay in 2004 (NOAA, 2004; unpublished data Gaydos et al.[1]). From September 2005 through April 2006, another UME was declared, this one similar to the 1999-2000 event in terms of spatial and temporal distribution in that the mortalities spanned from east to west and lasted several months (unpublished data Gaydos et al.[1]). Over half (65.6%; 61/93) of the mortalities from the 2005-2006 event were inside the bays and estuaries (unpublished data Gaydos et al.[1]).

During the events, necropsies and sample analyses were conducted when possible on the dolphins with the least amount of post-mortem damage. In the 1999-2000 UME, 41% (11/27) of the samples tested were positive for brevetoxins (unpublished data Gaydos et al.[1]). All of the tested dolphins from the 2004 event were positive for brevetoxins (n = 39) and 81% (38/47) of dolphins that were tested from the 2005-2006 UME were positive (unpublished data Gaydos et al.[1]). The highest concentrations of toxins were found in the stomach contents, gastric fluid, and fecal samples (unpublished data Gaydos et al.[1]). Brevetoxicosis through ingestion was determined to be the cause of all three UMEs in the Northwest Florida Panhandle (unpublished data Gaydos et al.[1]). Preliminary results from stomachs collected from the 2004 UME had high stomach content weight and over half of the stomachs had Clupeidae. From this analysis, it was suggested that dolphins might have foraged in association with commercial fisheries prior to death (NOAA, 2004). To date, stomach content analysis on dolphins from the UMEs

have not been completed nor reported. To understand these UMEs further, there needs to be information on diet of bottlenose dolphin in the Northwest Florida Panhandle.

Brevetoxins accumulate in food webs (Flewelling et al., 2005; Naar et al., 2007; Fire et al., 2008a), which may explain the delayed mortalities observed in UMEs involving brevetoxins. Apart from toxin accumulation, negative effects on fish density and species richness have been attributed to *K. brevis* blooms (Gannon et al., 2009). If the main prey species for bottlenose dolphins are greatly affected by *K. brevis* blooms, it might be expected that bottlenose dolphins will alter foraging strategies to fulfill their dietary needs. Such changes have been observed in Sarasota Bay, FL (Powell, 2009). Bottlenose dolphins in Sarasota typically forage individually in shallow areas; however, once a large-scale *K. brevis* bloom occurred, significantly higher rates of depredation (when dolphins remove or damage bait or fish caught by recreational anglers) were observed (Powell, 2009). Whether or not this foraging change occurs and what species of prey become more important to bottlenose dolphins in the Northwest Florida Panhandle have not been previously studied.

The purpose of this study was to investigate the diet of bottlenose dolphins in the Northwest Florida Panhandle and determine whether *K. brevis* blooms affect diet. Previous studies have yet to investigate changes in the diets of bottlenose dolphins in relation to *K. brevis* blooms. It was hypothesized that dolphins that stranded during and shortly after the *K. brevis* bloom would have different diets from dolphins that stranded in the absence of the bloom. In addition, this study investigated other factors that may affect diet such as stranding inside or outside bays, dolphin sex, dolphin length, and time of year.

Methods

Stomach collection

The Northwest Florida Panhandle spans from the Florida-Alabama boarder (approximately -87.55°W) east to the Aucilla River (approximately -83.99°W). Twenty-six whole stomachs were collected from stranded bottlenose dolphins from November 2006 to March 2009 along the Northwest Florida Panhandle (Table 2.1 and Figure 2.1). Fourteen stomachs were from animals that stranded inside Pensacola Bay, Choctawhatchee Bay, or St. Andrews Bay; two animals stranded near the sound or dredged channel ("bay;" Tables 2.2 and 2.3 and Figure 2.1). There were 9 stomachs collected from dolphins that stranded outside any bays/estuaries, along the Gulf of Mexico ("coast;" Tables 2.2 and 2.3, Figure 2.1). Total body length for the dolphins averaged 233 ± 37 cm with a range of 139-305 cm (Table 2.1). The smallest dolphin to have identifiable prey had a total length of 169.5 cm. One dolphin that was 139 cm was excluded from the study since it was likely a dependent calf (according to Wells and Scott, 2008) and not a good representation of bottlenose dolphin diet. Fourteen of the stranded bottlenose dolphins were female, and 11 were male (Table 2.2). Six of the 24 strandings had evidence of human interaction: bullet fragments (n = 1), propeller lesions (n = 1), fishing hook in forestomach (n = 1) and fisheries entanglement marks (n = 3; Table 2.1).

Ten stomachs were collected from bottlenose dolphins that stranded before the 2007 *K. brevis* bloom (November 2006-July 2007), and 1 stomach was collected 14 months after the bloom in March 2009; these were classified as "non-bloom" stomachs

(Table 2.3 and Figure 2.1). A total of 14 stomachs were collected during and 6 months after the 2007 *K. brevis* bloom and these were classified as "bloom" stomachs (October 2007-March 2008; Table 2.3 and Figure 2.1). Stomachs were classified as "bloom" if they were collected from dolphin strandings during which *K. brevis* cell concentrations were higher than 100,000 cells/L of water and 6 months after. Water sampling for harmful algal blooms in the Northwest Florida Panhandle is sporadic. To be conservative, all water samples collected in the Northwest Florida Panhandle were used to classify bloom conditions regardless of where samples were collected. Brevetoxins have been detected in the majority of fish and dolphin tissues up to 1 year and 9 months, respectively, after *K. brevis* blooms (Naar et al., 2007; Fire et al., 2007; Fire et al., 2008b). Over 80% of fish collected 3-8 months after *K. brevis* bloom in Sarasota were positive for brevetoxins; however, these concentrations were much lower than fish collected during blooms (Fire et al., 2008a). Above-average dolphin mortalities involved in the 3 UMEs along the Northwest Florida Panhandle occurred up to 5 months after the *K. brevis* blooms (NOAA, 2004, unpublished data Gaydos et al.[1]). Although brevetoxins are still present in the environment 6 months after a bloom, the lethal effects of brevetoxins on fish and dolphins are less likely (Naar et al., 2007, Fire et al., 2007, Fire et al., 2008a, NOAA, 2004; unpublished data Gaydos et al.[1]). For this study, 6 months after high concentrations of *K. brevis* was used to separate dolphins likely affected by the bloom from dolphins not affected. The 100,000 *K. brevis* cells/L concentration was chosen for this study because this was the same threshold concentration used in the Gannon et al. (2009) study on the effects of *K. brevis* on fish abundance. According to Florida Fish and Wildlife Research Institute (FWRI) harmful algal bloom database, *K.*

brevis was above 100,000 cells/L in waters along the Northwest Florida Panhandle from September 24, 2007 to December 19, 2007 (Figure 2.2; FWRI, queried by Paula Scott on April 4, 2009).

Stomach examination and identification

Whole stomachs were frozen after collection and then thawed to room temperature before they were examined. Stomachs were examined from the duodenum to the forestomach. Total contents were then carefully collected from each stomach chamber and weighed to the nearest gram. Whole or incomplete fish or shrimp were separated from the total contents and rated on a percentage of decomposition scale ranging from 1-100% (Figure 2.3). The total length of each specimen was measured using a digital caliper to the nearest 0.01 mm and when possible, otoliths were removed from the skulls for identification. The remaining stomach contents were placed in a glass jar over a 0.05 mm sieve. Tap water ran continuously in the jar for about 15 minutes or until the water in the jar was clear. Free otoliths and squid beaks were separated and stored for identification.

Otoliths were identified to genus and species when possible using the Panama City Otolith Identification Guide (NOAA, Panama City Laboratory, http://www.pclab.noaa.gov/content/40_Fisheries_Biology/05_Otolith_Guide/Otolith_Guide.php), Barros (1993), and Anàlisi de formes d'otòlits (AFORO) website (http://www.cmima.csic.es/aforo/). Otolith identifications were cross-checked by Dr. Damon Gannon to confirm species identification. Right and left otoliths were counted. Otoliths were rated on a scale of digestion ranging from 0 to 5 based on surface texture

and shine, condition of edge lobulations, and degree of opacity (Figure 2.4; Recchia and Read, 1989). Whole otoliths with digestion ranges between 0-2 were measured to the nearest 0.01 mm total length or weighed to 0.001 g. Clarke (1986) was used to identify family of squid beaks found in dolphin stomachs. The number of upper and lower squid beaks were counted.

Analysis

The frequency of occurrence (%O), percent by numerical abundance (%N), and percent by reconstructed mass or weight (%W) were calculated for prey items that were identified. The frequency of occurrence was calculated by dividing the number of stomachs with a particular prey species by the total number of stomachs. The total number of prey was determined by using the highest count of right or left otoliths for each stomach. If right or left otoliths could not be determined, then the total number of otoliths of that species was divided by 2 to obtain the number of prey for that species in each stomach. The highest number between count of upper and lower squid beaks were used to determine the total number of squid prey. Percentage by numeric abundance was calculated by dividing the number of prey of a particular species by the total number of prey found in each stomach, and averaged for all stomachs. Equations relating otolith length or weight to fish weight from literature were used to back calculate the weight of the fish in the dolphin's stomach using otoliths with digestion ranges between 0-2 (Table 2.4). The calculated fish weight was averaged and used to estimate weight of fish from the same species with otoliths rating of 3-5. Percentage by reconstructed mass was

calculated by dividing the weight of a prey species in a single stomach by the total reconstructed weight of all prey in the stomach, then averaged for all stomachs.

The Shannon Index was used to calculate prey species diversity (Shannon and Weaver, 1949). Stomach content weight, average percentage of decomposition of partially intact prey, prey re-calculated length, frequency of occurrence, percent by numeric abundance, percentage by weight, and Shannon Index were used to compare results between males and females, bay and coast strandings, and paired bloom and non-bloom strandings. To correct for stranding time of year, which may affect diet, the non-bloom stomachs were paired by nearest stranding date with bloom stomachs to compare dietary differences in the presence and absence of a *K. brevis* bloom (Table 2.5). Then, when possible, stomachs were paired based on stranding location and sex (Table 2.5). Dolphin length and stranding month were investigated using the Shannon Index and percent of numeric abundance of most common prey family.

Mann-Whitney U tests were used to compare stomach content weight between bloom and non-bloom strandings, bay and coast strandings, and female and male strandings. Chi square tests of independence were used to compare prey abundance results between bloom and non-bloom strandings, bay and coast strandings, and female and male strandings. Spearman's rank correlations were used to compare Shannon Index to dolphin length, Shannon Index to stranding time of year, and the abundance of the most frequently observed prey family to dolphin length. To compare Shannon Index values by stranding time of year, the number of days between the stranding date to the coldest time of the year (February 1) up to the warmest time of year (August 1) were

used. Mann-Whitney U tests and Spearman rank correlation were calculated using SAS 9.1.3 software (SAS Institute Inc., 2007).

Results

Total stomachs

Twenty-two of 25 bottlenose dolphin stomachs contained prey items of fish, shrimp, or squid. Total contents from each stomach had an average weight of 299 ± 425 g (range 0-1465 g; Table 2.6). Thirty-four different prey species were identified in 22 stomachs of bottlenose dolphins from the Northwest Florida Panhandle.

By frequency of occurrence, spot *Leiostomus xanthurus* (54.6%) and seatrout *Cynoscion spp*. (50.0%) were observed most often (Table 2.7). Pinfish *Lagodon rhombiodes* and shrimp, Family Penaeidae, had a frequency of 36.4% and 31.8% respectively (Table 2.7). Silver perch *Bairdiella chrysoura* were present in 7 (31.8%) stomachs (Table 2.7). Atlantic croaker *Micropogonias undulatus* and squid, family Loliginidae, were found in 6 stomachs (27.3%; Table 2.7). At the level of family, the family Sciaenidae (i.e., croakers) had the highest frequency of occurrence of 77.3%, followed by Sparidae (porgies; 36.4%), Penaeidae (31.8%), and Loliginidae (27.3%; Table 2.7).

A total of 2031 prey items were counted using the number of right and left otoliths for fish or upper and lower beaks for squid. Spot, squid, pinfish, and Atlantic croaker had the highest percentage of numerical abundance in all stomachs. Spot were present with a proportion of numerical abundance of 20.4% (Table 2.7). Squid had a prey abundance of 10.9%; pinfish had an abundance of 10.3%; and Atlantic croaker had

an abundance of 8.5% (Table 2.7). By family, Sciaenidae had the highest percentage of numerical abundance of 43.3%, followed by Sparidae (12.0%), and squid (10.9%; Table 2.7).

A total of 395 otoliths classified on a scale of digestion damage from 0-2 were used to reconstruct fish length and weight using equations found in literature (Table 2.4 and Figure 2.4). Spot had the highest proportion of reconstructed biomass accounting for 41.9% of the combined biomass of prey (Table 2.7). Pinfish accounted for 17.0% of the total reconstructed weight for all dolphin stomachs (Table 2.7). Atlantic croaker had a proportion of reconstructed mass of 15.9%, and silver perch made up 9.7% of total prey weight (Table 2.7).

Undamaged otoliths with digestion ratings between 0-2 were used to calculate fish length. The majority of prey were within a range of 49.3-160.4 mm (Table 2.8). Spot had an average reconstructed standard length of 126.0 ± 22.8, while pinfish had an average standard length of 101.7 ± 21.8 (Table 2.8). The average total length of Atlantic croaker was 140.9 ± 6.1 (Table 2.8). The Shannon Index for diversity in diet ranged from 0.3 to 2.08 with an average of 0.89 ± 0.61 (Table 2.9).

Bloom vs. Non-bloom

Diet comparisons among stomachs collected during the bloom and non-bloom periods were made using the paired stomachs from Table 2.5. Average weight of stomach contents was significantly higher for stomachs collected during the *K. brevis* bloom, referred to as “bloom stomachs” (332 ± 453 g) than stomachs collected in the absence of a bloom, referred to as “non-bloom stomachs” (74 ± 215 g, U = 5.8179, n =

18, p = 0.02; Table 2.6). For bloom stomachs, 10 out of 14 stomachs collected during the bloom contained partially digested prey items; whereas only 2 out of 11 stomachs collected during the non-bloom months had partially digested prey items (Table 2.10).

A total of 11 species were observed only in bloom stomachs and 10 species were identified only in non-bloom stomachs. Thirteen species representing 9 families were found in both bloom and non-bloom stomachs. Squid had a frequency of 11.1% for paired bloom and 55.6% for non-bloom stomachs (Figure 2.5). Bloom stomachs had a higher frequency for Penaeidae (44.4%) and Mugilidae (44.4%) than non-bloom stomachs (11.1% for both, Figure 2.5). Sciaenidae had the highest frequency in both bloom (66.7%) and non-bloom stomachs (66.7%; Figure 2.5).

Stomachs collected from dolphins that stranded during bloom months had more prey items than stomachs collected from dolphins that stranded in the bloom's absence (1130 and 610 respectively). Bloom stomachs had a larger numeric abundance for spot (39.7%, number of prey or n = 510) than non-bloom stomachs (1.1%, n = 7; Table 2.11). Non-bloom stomachs had higher percent by numeric abundance and higher number of prey for Atlantic croaker (11.4%, n = 244) than bloom stomachs (0.5%, n = 3; Table 2.11). Bloom stomachs had a higher number of silver perch (166 prey) than non-bloom stomachs (91 prey); however, silver perch in non-bloom stomachs made up a higher percentage of numeric abundance than bloom stomachs, 9.4% and 4.6% respectively (Table 2.11). Pinfish were more abundant in bloom stomachs (11.5%, n = 75) than non-bloom stomachs (2.9%, n = 9; Table 2.11). Squid had a percent of numeric abundance at 32.3% and a total of 33 squid were identified in non-bloom stomachs, whereas bloom stomachs had 0.2% abundance of squid and 3 squid were identified (Table 2.11 and

Figures 2.6-2.8). Sciaenidae were more abundant and had a higher number of prey in bloom stomachs, 49.3% and 748 respectively; than non-bloom stomachs, 36.2% and 393 respectively (Table 2.11 and Figures 2.6-2.8). Percent by numeric abundance of prey species and families were significantly different between bloom and non-bloom stomachs (by species $\chi^2 = 983.18$, df = 30, $p < 0.01$ and by families $\chi^2 = 203.23$, df = 13, $p < 0.01$; Table 2.11 and Figure 2.6).

Spot (88.0%) had a higher reconstructed mass for bloom stomachs than non-bloom stomachs, 7.5% (Table 2.12). Atlantic croaker (29.3%) and silver perch (23.5%) had higher reconstructed mass for non-bloom stomachs than bloom stomachs, 0.1% and 6.3% respectively (Table 2.12). By family, Mugilidae (13.7%) and Clupeidae (13.2%) had higher reconstructed mass for non-bloom stomachs than bloom stomachs (0.5% and 0%, respectively; Table 2.12). Fish lengths were back calculated from otoliths recovered in dolphin stomachs. Due to unequal sample sizes of undamaged otoliths, comparisons between non-bloom and bloom stomachs were only possible for silver perch. Silver perch total length was even between non-bloom stomachs (103.2 ± 3.0 mm) and bloom stomachs (99.7 ± 5.5 mm; Table 2.13).

Stranding Location

Average weight of stomach contents was higher for stomachs collected from dolphin strandings inside bays and sounds, referred to as "bay stomachs" (366 ± 462 g) than stomachs collected from dolphin strandings along the coast, referred to as "coast stomachs" (120 ± 259 g; U = 4.4915, n = 25, p = 0.0341; Table 2.6). Dolphin stomachs collected from strandings inside the bays or sounds had 12 species that had not been

observed in stomachs from the coast. Dolphins that stranded along the coast had 8 species of prey in the stomach contents that were not found in the stomach contents of bay strandings. Thirteen species were common to both bay and coast stomachs.

Frequencies of occurrence were different between dolphins that stranded inside bays and along coast for silver perch (26.6% bays, 42.9% coast), pinfish (40.0% bays, 28.6% coast), and striped mullet *Mugil cephalus* (33.3% bays, 0% coast; Figure 2.9). Sciaenidae had the highest frequency for both bay and coast stomachs with 80.0% and 71.4% respectively (Figure 2.9). Frequency of occurrence was similar between bay and coast dolphins for Loliginidae (26.7% and 28.6%; Figure 2.9). The frequency of Sparidae was 40.0% for bay stomachs and 28.6% for coast stomachs (Figure 2.9).

Stomachs collected from dolphins that stranded inside the bays had higher numeric abundance of spot (25.1%) than dolphins that stranded along the coast (10.3%; Figure 2.10). Stomachs collected along the coast had higher abundances of silver perch (10.1%) than bay stomachs (3.1%; Figure 2.10). Pinfish were more abundant in bay stomachs (14.2%) than in coast stomachs (2.1%; Figure 2.10). The percent by numeric abundance for prey families between bay and coast stomachs were similar for squid (10.6% and 9.9%, respectively) and Sciaenidae (44.7% and 40.1% respectively; Figure 2.11). Sparidae had a higher numeric proportion for bay stomachs (14.8%) than coast stomachs (4.8%; Figure 2.11). Penaeidae had a higher abundance in coast stomachs (7.2%) than bay stomachs (0.3%; Figure 2.11). The high abundance of unidentified fish in the stomachs of dolphins that stranded along the coast is due to the severe damage of the otoliths from these stomachs, which limited species identification (Figures 2.10 and 2.11). Abundance of prey species between bay and coast stomachs were significantly

different for species and families (by species $\chi^2 = 1052.17$, df = 34, $p < 0.01$ and by families $\chi^2 = 262.77$, df = 14, $p < 0.01$; Figures 2.10 and 2.11).

Pinfish had a higher reconstructed percent by weight for bay stomachs (20.9%) than coast stomachs (7.6%; Table 2.14). Silver perch had a higher reconstructed percent by weight for coast stomachs (20.3%) than bay stomachs (5.3%; Table 2.14). Sciaenidae made up the majority of the reconstructed weight for both bay and coast stomachs (62.8% and 79.2% respectively; Table 2.14).

Spot from bay stomachs had an average standard length of 126.3 ± 22.8 mm, and spot from coast stomachs had an average standard length of 112.8 ± 6.1 mm (Table 2.15). There were more spot otoliths available for fish length calculations in bay stomachs (n = 207) than coast stomachs (n = 5; Table 2.15). Silver perch reconstructed fish lengths were nearly even between bay stomachs (100.5 ± 6.7 mm) and coast stomachs (103.4 ± 3.1 mm; Table 2.15).

Female vs. Male

Weight of stomach contents were not significantly different between stomachs collected from male dolphins, referred to as "male stomachs," and stomachs collected from female dolphins, referred to as "female stomachs" (U = 0.6013, n = 25, p = 0.44; Table 2.6). Stomachs from female dolphins had 9 species not observed in the stomachs from male dolphins; whereas stomachs from male dolphins had 7 prey species not observed in stomachs of female dolphins. Seventeen species were found in both female and male stomachs. Silver perch had different frequencies of occurrence between female

stomachs (23.1%) and male stomachs (44.4%). Sciaenidae had a frequency of 88.9% in male stomachs and 69.2% in female stomachs (Figure 2.12).

Stomachs collected from female dolphins had larger numeric abundance of spot (28.5%) than male dolphins (8.6%; Figure 2.13). Female stomachs had 455 spot prey whereas male stomachs had only 101. Male stomachs had higher percentage of numerical abundance for Atlantic croaker (16.0%, n = 259) and silver perch (11.1%, n = 252) than female stomachs (3.3%, n = 6, and 1.3%, n = 7 respectively; Figure 2.13). Penaeidae had higher percent by numeric abundance for males (5.6%) than females (0.4%; Figure 2.14). Abundance of prey species and families between male and female stomachs were significantly different ($\chi^2 = 974.32$, df = 34, $p < 0.01$ and $\chi^2 = 198.58$, df = 14, $p < 0.01$; Figures 2.13 and 2.14).

A total of 1268 prey items were found in stomachs from male dolphins; whereas 763 prey items were observed in female stomachs. However, 8 stomachs from female dolphins had partially digested contents that could be weighed and rated on percent of decomposition, and only 2 male stomachs had partially digested prey (Table 2.10). Female stomachs also had a larger number of otoliths that could be used for calculations (n = 247) than male stomachs (n = 148). Spot had a higher percent of reconstructed weight for females (56.8%) than males (25.1%; Table 2.16). Stomachs collected from male dolphins had a higher percent by reconstructed weight for silver perch than stomachs from females, 18.5% and 1.9% respectively (Table 2.16). Pinfish from female stomachs had larger standard lengths (111.5 ± 13.9 mm) than pinfish from male stomachs (73.5 ± 14.6; Table 2.17). Spot had an average standard length of 124.6 ± 22.2 mm in

dolphin stomachs from females; whereas spot from the stomachs of male dolphins had a larger average length of 143.3 ± 24.8 mm (Table 2.17).

Dolphin Length

Sparidae had higher numeric abundances of 86.0-94.8% in smaller dolphins (total length 197.5 cm and 210.5 cm) than larger dolphins with numeric abundances of 3.6-27.2% (total length ≥ 229.0 cm; Figure 2.15). Sciaenidae had a higher average of 78.5% abundance in larger dolphins than in smaller dolphins with an average of 33.4%; however, this result was marginally insignificant (Spearman = 0.4795, p = 0.0515; Figure 2.15). Shannon Index value for prey diversity appeared to increased with dolphin length; however, this relationship was not statistically significant (Spearman = 0.4057, p = 0.0681; Figure 2.16).

Stranding Date

Diet differences among seasons were not compared due to small sample size; however, abundance of the top 4 prey families and Shannon Index were used to investigate any possible differences in diet to time of year. There were no trends in abundance of Loliginidae, Mugilidae, Sparidae, or Sciaenidae with respect to stranding date (Figure 2.17). In addition, diversity of prey, calculated by the Shannon Index, was not correlated with time of year (Spearman = 0.2281, p = 0.3786; Figure 2.18).

Discussion

There were striking differences in diet between dolphins that stranded in the absence of the *K. brevis* bloom versus dolphins that stranded during and shortly after the bloom. Dolphins that stranded during bloom conditions consumed more demersal prey, had higher stomach content weights, and fewer digested prey than dolphins that stranded in the bloom's absence. Loliginidae (squid) had a higher frequency of occurrence and abundance in non-bloom stomachs than bloom stomachs. Squid, however, are equal in bay and coast stomachs, suggesting this difference could be due to the *K. brevis* bloom. This study was the first to compare the diet of dolphins before, during, and after a *K. brevis* bloom. Information on diet of dolphins that stranded in the absence of a *K. brevis* bloom from this study can be used to understand the 3 previous UMEs in the Northwest Florida Panhandle. Findings of this study may be further supported through a continuation of diet studies, finalized UME stomach content analysis, brevetoxin analysis on squid, and recovery time of prey after a *K. brevis* bloom.

Information about the diet of dolphins in the Northwest Florida Panhandle has been determined through the results of this study. The analysis of stomachs from this study had similarities to other studies on dolphins in the Southeast United States in that Sciaenidae and other sound producing fish make up the majority of the diet. Differences were observed in diet between stranding location (bay vs. coast) in this study and were found in other studies as well (Barros, 1993; Barros and Wells, 1998; Gannon and Waples, 2004). Male and female diet differences in the Northwest Florida Panhandle were significant, which supports foraging behavioral differences between males and females. The diet of dolphins from the Northwest Florida Panhandle were similar to diet

analysis in other studies in that Sciaenidae are the most important prey family and diet differences occur between dolphin stranding location and sex.

Bloom vs. Non-bloom

The stomachs of dolphins collected during the *K. brevis* bloom had higher stomach contents and larger number of prey items than stomachs collected in the absence of the bloom. Dolphins from the Northwest Florida Panhandle that stranded during bloom months had pinfish and spot in the stomachs; whereas dolphins during non-bloom months consumed more squid and Atlantic croaker. The pairing of stomachs collected during the bloom to stomachs collected in non-bloom periods controlled for stranding time of year and when possible location, sex, and length. Thus, differences in diet that were observed in this study are likely due to the *K. brevis* bloom and not another variable. Larger sample size would have allowed for better pairing among bay and coast stomachs as well as larger sample size for comparison. Further evidence that diet differences were due to the bloom include lack of Loliginidae in bloom stomachs, fuller stomachs from bloom strandings, and higher numeric abundance of demersal prey in stomachs collected during the bloom.

Squid had a higher frequency of occurrence and abundance in stomachs collected during non-bloom months than stomach collected during bloom months. Squid, however, were equal between diets of dolphins stranded in the bay and coast, suggesting the difference in squid from stomachs collected during non-bloom periods and bloom periods could be due to the *K. brevis* bloom. The lack of squid in stomachs collected during the bloom could be due to lack of squid available in the environment. Perhaps, squid

populations in the nearshore waters of the Northwest Florida Panhandle may have been nearly decimated due to brevetoxins or other environmental variables such as changes in salinity. For example, another species of cephalopod, *Octopus* cf. *mercatoris*, was present in St. Joseph Bay prior to the 1999 *K. brevis* bloom, but only one individual was found 3 years later (Tiffany et al., 2006). Alternatively, squid were not found in stomachs of dolphins that stranded during the bloom because squid might not accumulate brevetoxins to levels comparable to fish. Perhaps the dolphins that consumed squid during the bloom did not die during the *K. brevis* bloom. Squid (n = 4) collected in Sarasota Bay within 3 months of a *K. brevis* bloom had no detectable levels of brevetoxins (Fire et al., 2008a). Fire et al. (2008a) did not report whether the 4 squid that were analyzed were chosen randomly or if they were the only squid collected for testing. Unfortunately, there have been no observations of squid mortalities or records of squid abundance in the Northwest Florida Panhandle in the past 10 years. Additional studies should be conducted to determine the impact *K. brevis* blooms may or may not have on squid populations and subsequently on dolphin diet.

Dolphins that stranded during the bloom had a larger mean stomach content weight than dolphins that stranded in the absence of the bloom. During the 2004 bottlenose dolphin UME in Northwest Florida Panhandle, examined stomachs were described as full with an average contents weight of 773 g (NOAA, 2004). The higher stomach content weights for strandings during bloom months and previous UMEs indicate that dolphins foraged prior to death. Four stomachs collected during bloom months in this study had averages of percent of digestion for prey items ranging from 10-52.5%. None of the non-bloom dolphins had an average percent of digestion below

75.8%. A lower percentage of digestion in prey items of stomach contents could also indicate a short time between prey consumption and death. This acute death for UME dolphins may indicate that dolphins were healthy prior to consumption, and perhaps high levels of toxins consumed from prey were the cause of death. The relationship between acute death and brevetoxicosis has not been determined at this time as research on the subject is limited.

Dolphins that stranded during bloom months in this study consumed mostly demersal fish, which may have higher levels of brevetoxins and retained these toxins for longer periods of time. Sciaenidae, Sparidae, and Haemulidae are demersal feeders and made up 72.9% of the prey items found in bloom stomachs of this study. In contrast, only 43.9% of prey items from non-bloom stomachs were composed of Sciaenidae, Sparidae, and Haemulidae. Demersal fish may be more sensitive to *K. brevis* blooms and may become easier prey for bottlenose dolphins (Landsberg, 2002; Gannon et al., 2009). Brevetoxin levels were the lowest (range 5-1838 ng PbTx-3/g) for mullet (pelagic filter-feeder) compared to pinfish, pigfish, and spot (demersal feeders) during *K. brevis* blooms (range = 6-10844 ng PbTx-3/g; Fire et al., 2008a). In the same study, 67% of mullet collected 3 months after the bloom were positive for brevetoxins, whereas 88%, 90%, and 100% of pinfish, pigfish, and spot were positive (Fire et al., 2008a). Dolphins that stranded in the Northwest Florida Panhandle during bloom months may have been exposed to higher levels of brevetoxins due to foraging of demersal prey.

The bioaccumulation of brevetoxins in dolphins through the ingestion of Clupeidae prey (pelagic filter feeders) is a hypothesis that has been proposed to explain the dolphin mortalities associated with *K. brevis* blooms (NOAA, 2004; Flewelling et al.,

2005). According to the 2004 NOAA Interim Report of incomplete stomach content analysis, Clupeidae were found in 14 of the 28 stomachs examined (50%). Clupeidae are represented in 4 out of 17 stomachs (24%) that were examined in the 2005-2006 UME (unpublished data Gaydos et al.[1]). However, the report also mentions that hundreds, possibly thousands, of Sciaenidae otoliths were present in the 2004 and 2005-2006 UME (NOAA, 2004; unpublished data Gaydos et al.[1]). The assumption of Clupeidae as a major component of dolphins' diet during UMEs is based on incomplete frequency of occurrence data and not numeric or biomass data that are a better representation of important prey to the caloric needs of dolphins. For example, a higher number of Clupeidae were identified in stomachs of dolphins during the bloom than dolphins that stranded in the bloom's absence; however, Clupeidae did not make up the majority of the diet of bloom dolphins in terms of numeric abundance and biomass. This study contradicts bioaccumulation through Clupeidae hypothesis in that the frequency of Clupeidae in this study were lower than the frequency of Clupeidae in the 2004 UME; Clupeidae were equal in frequency of occurrence and percent by numeric abundance of bloom and non-bloom dolphins; and were one of the least important prey to dolphins that stranded during bloom months. The 2004 UME was the basis for this hypotheses, but this event was different in spatial and temporal terms compared to the 1999-2000 and 2005-2006 events (NOAA, 2004; unpublished data Gaydos et al.[1]). In addition, harmful algal bloom sampling in 2004 did not indicate high concentrations of *K. brevis* in the Northwest Florida Panhandle although high chlorophyll concentrations were evident from satellite imagery near St. Joseph Bay (NOAA, 2004). *Karenia brevis* cells were present during the 1999-2000 and 2005-2006 events throughout the Northwest Florida

Panhandle (Gaydos et al.[1]). This hypothesis may explain why a large number of dolphin mortalities were isolated in St. Joseph Bay in only 3 months; however, this may not be adequate to explain prolonged mortalities such as the 1999-2000 and 2005-2006 UMEs as *K. brevis* blooms are not always the same.

Brevetoxin accumulation through demersal prey might provide a better explanation for prolonged dolphin mortalities in relation to *K. brevis* blooms. Demersal fish during and after *K. brevis* blooms may be the vector of brevetoxins to bottlenose dolphins. When there were high *K. brevis* cell concentrations in the area, some dolphins may have foraged on demersal fish that were negatively impacted or killed by *K. brevis* (Gannon et al., 2009). This may explain the dolphin mortalities during the bloom. Over time as the *K. brevis* cells died out, the brevetoxins remain in the ecosystem, settling into the sediment and on the periphyton of seagrass (Flewelling et al., 2005; Flewelling, 2008; Mendoza et al., 2008). Organisms such as bivalve mollusks, shrimp, harpacticoid copepods, crabs, amphipods, polychaetes, and seagrass periphyton that accumulate biotoxins are preyed upon by maturing fish such as pinfish, spot, pigfish, and silver perch (Hansen, 1969; Livingston, 1982; Tester et al., 2000; Linares et al., 2009; Sotka et al., 2009). As observed in this study and other studies in the southeast, bottlenose dolphins forage on pinfish, spot, pigfish, and silver perch which may have accumulated brevetoxins from a K. *brevis* blooms months ago (Barros and Odell, 1990; Barros, 1993; Barros and Wells, 1998; Gannon and Waples, 2004; Pate, 2008).

Further investigation of vectors of brevetoxin accumulation in bottlenose dolphins would require the following: foraging behavioral studies on bottlenose dolphins in the Northwest Florida Panhandle, natural brevetoxins accumulation for demersal and pelagic-

filter feeding prey, and continued collection of whole stomachs from stranded dolphins. Completed analysis of previous UMEs may support the differences observed in this study. However, more stomachs and consistent stranding data during non-bloom periods are vital to understand the UMEs in the Northwest Florida Panhandle. To investigate UMEs it is important to know diet of the species of marine mammals involved during non-UME conditions. Further research on distribution, abundance, and brevetoxin accumulation in squid, demersal fish prey, and filter feeding prey are needed.

Most Important Prey

Sciaenidae were most abundant and frequent in the diet of bottlenose dolphins in the Northwest Florida Panhandle regardless of stranding location, temporal relation to *K. brevis* blooms, or sex. The most abundant species of the family Sciaenidae in this study were spot, Atlantic croaker, silver perch and seatrout *spp.* (Table 2.7). The importance of Sciaenids in this study are similar to bottlenose dolphin studies in the east coast of Florida, the Gulf of Mexico, South Carolina, and North Carolina with percentages of numeric abundance ranging between 53-73% (Barros and Odell, 1990; Barros, 1993; Barros and Wells, 1998; Gannon and Waples, 2004; Pate, 2008). Although dolphins may forage on different species of Sciaenidae depending on availability in the environment, the importance of Sciaenidae in the diets of dolphins in the Southeast is consistent with results of this study.

Pinfish (family Sparidae) are widely found throughout the estuaries of the Gulf of Mexico and from the Mid-Atlantic to Bermuda (Hoese and Moore, 1998). Yet this study and stomach analysis of dolphins from Sarasota Bay, Florida are the only studies to

report frequencies over 36.4% and abundances over 9.4% of pinfish (Table 2.6; Barros and Wells, 1998; Berens McCabe et al., 2010). Diet studies of resident dolphins stranded in Sarasota, Florida from 1984-1996, had frequency of 56.3% and numeric abundance of 70% for pinfish, the highest of all prey identified in stomachs (Barros and Wells, 1998). Another common species in the diet of bottlenose dolphins in North America are Atlantic croaker (Barros and Odell, 1990; Barros, 1993; Gannon and Waples, 2004; Pate, 2008), which do not inhabit Sarasota Bay, and thus resident dolphins in Sarasota might feed on pinfish instead (Barros and Wells, 1998). However, in the Northwest Florida Panhandle, both Atlantic croaker and pinfish are present, so why do diets of dolphins from this study have higher frequencies and abundances of pinfish? Fish density changes between Atlantic croaker and pinfish could have occurred in the Northwest Florida Panhandle. Atlantic croaker abundances were lower in areas with high salinity variance (Moser and Gerry, 1989). Perhaps a salinity variance caused lower densities of Atlantic croaker in the Northwest Florida Panhandle; thus, pinfish made up the dolphin's additional caloric needs as pinfish are tolerant of changes in salinity (Shervette et al., 2007). This may be the case for the Choctawhatchee Bay with a large amount of freshwater input, little mixing, and high salinity stratification (Livingston, 2001).

Penaeidae, or shrimp, were the third most frequently observed prey in stomachs of stranded dolphins in this study (31.8%; Table 2.7). Shrimp have been observed in stomachs from bottlenose dolphins in the Gulf of Mexico, particularly in Texas and Alabama with a frequency of occurrence of 28.0% (Barros and Odell, 1990). Shrimp were not present in the diets of dolphins from the Florida Keys and had a low frequency of occurrence at 4.5% for dolphins in south central Florida (Barros and Odell, 1990).

Shrimp had a frequency of occurrence of 26.0% of stomachs collected from dolphins in South Carolina (Pate, 2008). The high occurrence of shrimp in dolphin stomachs from Texas, Alabama, and South Carolina are thought to be due to dolphins feeding in association with shrimp vessels (Barros and Odell, 1990; Pate, 2008). The dolphins may have been feeding on shrimp that had escaped from the net through the by-catch reduction device. There are anecdotal reports and observations of dolphins in association with shrimp trawls in the Northwest Florida Panhandle (S. Bowen, unpublished observation; N. Lane personal communication). Therefore, the presence of shrimp in the stomachs of dolphins in this study could be due to dolphins feeding in association with shrimp vessels.

Loliginidae, or squid, were the fourth largest observed prey with a frequency of occurrence of 27.3% in this study (Table 2.6). Loliginidae were present in the diets of dolphins from the Gulf of Mexico and North Carolina (Barros and Odell, 1990; Gannon and Waples, 2004). Squid were not present in the stomachs of resident Sarasota dolphins despite squid being found in 18.2 % of stomachs collected in coastal waters near Sarasota Bay, Florida (Barros and Odell, 1990; Barros and Wells, 1998). Squid may be more important for the diet of dolphins in the Northwest Florida Panhandle.

Stranding Location

Differences in diet were observed between dolphins that stranded inside bays or sounds and dolphins that stranded outside bays along the coast of the Northwest Florida Panhandle. These differences are supported by the similarity of species found within estuaries and found in the diet of dolphins that stranded inside the bays; differences that

have been reported in other studies on stomach analysis; and evidence of dolphin site fidelity in the bays of the Northwest Florida Panhandle.

Stomachs collected from dolphins that stranded in the bays had a higher frequency of occurrence, percent of numeric abundance, and percent of reconstructed mass for spot and pinfish. Stomach analysis from bay strandings had a higher percentage of numeric abundance of spot than stomachs from coast strandings. The spot otoliths from the stomachs of bay dolphins in this study had an average recalculated standard length of 126.0 ± 22.8 mm (Table 2.15). Immature spot mature in the estuaries before migrating offshore in the fall to spawn (Parker, 1971; Hoese and Moore, 1998). Bay dolphins in this study consumed immature spot, which are found most frequently inside bays and estuaries. Pinfish were more abundant in dolphin stomachs collected from the bay than in dolphin stomachs collected from the coast; this could be attributed to the increased abundance of pinfish in bays (Nelson, 2002). Using trammel nets, gill nets, seine nets, bottom trawls, and hook and line, Nelson (2002) found more pinfish in bays and shallow waters than in deeper waters.

Silver perch had higher frequency of occurrence and proportion by numeric abundance for coast stomachs than bay stomachs despite these fish being found in estuarine habitats for all life stages (Mok and Gilmore, 1983). The reason for higher frequency and abundance of silver perch in stomachs of coast strandings compared to stomachs of bay strandings in this study could be due to higher abundance in coastal waters than inside bays. Fish abundance surveys in the St. Andrews Bay reported 10 species that made up over 97% of total fish catch; silver perch was not one of these 10 species (Pristas and Trent, 1978). Shrimp were more abundant in stomachs collected

from dolphins that stranded along the coast than stomachs collected from dolphins inside the bays. Perhaps this is due to interactions with commercial shrimp vessels, as vessels are not allowed to trawl inside the bays. The higher abundance of shrimp may also be due to depredation of shrimp bait used by recreational anglers. A fishing hook was found in one of the stomachs collected along the coast in this study.

Differences between dolphins that stranded along the coast and those that stranded inside estuaries have been found in other diet studies (Gannon and Waples, 2004). In North Carolina, bottlenose dolphins that stranded in estuaries mostly consumed Atlantic croaker, and those stranded along ocean beaches consumed mostly weakfish *Cynoscion regalis* (Gannon and Waples, 2004). Differences in prey of the North Carolina study and this study may be due to differences in prey distribution and abundance between North Carolina and Northwest Florida Panhandle. The majority of weakfish are found from New York to North Carolina; they are also found in the Gulf of Mexico (Wilk, 1979; Hoese and Moore, 1998). Diet studies of bottlenose dolphins that stranded in other bays in central Florida found that resident dolphins consumed mostly fish, while oceanic dolphins ate fish, squid and shrimp (Barros, 1993; Barros and Wells, 1998). Barros and Odell (1990) explain that the squid and shrimp in the stomachs of dolphins from Texas/Alabama are due to dolphins associating with shrimp vessels. This may also be true for this study; however, shrimp may also be present in diets of dolphins due to fishing depredation or dolphins foraging on shrimp.

Differences in diet of dolphins inside bays to dolphins along the coast may be related to population differences. Evidence of long-term dolphin residents were reported from studies within St. Josephs Bay and Apalachicola Bay (Balmer, 2007; Balmer et. al.

2008; Tyson, 2008). Resident dolphins that reside inside bays have different prey species or sizes in their environment, thus prey selection might differ from dolphins that reside along the coast in the Northwest Florida Panhandle.

In conclusion, the diets of dolphins in the Northwest Florida Panhandle differ by stranding location (bays versus coast) which was previously unknown in this area. Prey found in stomachs of dolphins inside the bays were consistent with the life stages and species of prey typically found in the bays along the Northwest Florida Panhandle. Dolphin site fidelity in the bays of the Northwest Florida Panhandle further supports the differences in diet between strandings in bays and strandings along the coast.

Females vs. Males

Female dolphins in the Northwest Florida Panhandle consumed a higher numerical abundance and larger number of spot prey; whereas males consumed a larger number and had a higher numerical abundance of Atlantic croaker and silver perch. Differences in diet between sex have also been observed in other studies; however, they are not always comparable to the differences in prey species observed in this study (Barros and Wells, 1998; Santos et al., 2007). Male dolphins from Sarasota, Florida consumed a larger amount of striped mullet *Mugil cephalus* than the females (Barros and Wells, 1998). Frequency and numeric abundance for striped mullet in this study were even for male and female dolphins. Squid found in stomach analysis of dolphins from South Carolina had an abundance of 32% for mature females and 5% for mature males (Pate, 2008). Squid numerical abundance in stomachs from this study were not as different; females had an abundance of 12.2% (n = 23) whereas males had an abundance

of 7.7% (n = 13; Figure 2.14). The differences in consumption between male and female dolphins indicate that males and females may have different foraging strategies or habitats, *e.g.*, shallow seagrass beds versus deeper channels (Barros, 1993; Barros and Wells, 1998; Santos et al., 2007). The high number of spot prey by females may be explained by the increased nutritional demand females have due to pregnancy and nursing. Additional research is needed to assess why these differences may occur.

Dolphin Length

Pinfish (Sparidae) have higher numeric abundance in smaller dolphins than larger dolphins. Perhaps pinfish are easy prey for younger dolphins to catch while they forage in the shallow seagrass beds. As dolphins mature, there was an increase in the abundance of Sciaenidae such as spot. Increase in spot abundance with maturity has been observed in stomach content analysis of bottlenose dolphins in South Carolina (Pate, 2008). Immature females and males had spot abundances of 6% and 3%, respectively; in the same study mature females and males had abundances of 12% and 23%, respectively (Pate, 2008). Perhaps dolphins become better at hunting soniferous prey as they age because they gain experience with searching and capturing prey.

Stranding Date

No trends were found relating in prey species or diversity to dolphin stranding date. Low sample size and short time duration of this study limited the ability to compare diet among seasons. Significant differences in diet among seasons have been observed in other studies (Gannon and Waples, 2004; Pate, 2008). Weakfish were more important in

diets of bottlenose dolphins sampled in North Carolina in winter and spring than fall and summer (Gannon and Waples, 2004). The diet differences of bottlenose dolphins among seasons in South Carolina reflected the differences in prey availability between seasons (Pate, 2008). Differences and diversity in diet among seasons or stranding day may become more apparent over time with additional stomach analysis of dolphins from the Northwest Florida Panhandle.

Summary

1. Sciaenidae are the most important prey for bottlenose dolphins in the Northwest Florida Panhandle regardless of stranding location, temporal relation to *K. brevis* blooms, or sex.
2. Dolphins that stranded during bloom conditions consumed more pinfish and spot; and non-bloom dolphins ate more squid and Atlantic croaker. Differences in diets between non-bloom and bloom strandings are supported by the lack of squid in bloom stomachs, fuller bloom stomachs, and higher abundances of demersal prey in bloom stomachs.
3. Dolphins that stranded in the bay had a higher abundance of spot and pinfish, whereas dolphins that stranded along the coast had a higher abundance of silver perch and shrimp.
4. Female dolphins consumed more catfish, pigfish, and spot; whereas males consumed more Atlantic croaker and silver perch. Differences in diet between sex have been observed in other studies (Barros and Wells, 1998; Santos et al., 2007; Pate, 2008).

5. The abundance of Sciaenidae increased as bottlenose dolphins in the Northwest Florida Panhandle matured; however, results are insignificant at this time.
6. No temporal trends in diet were observed in this study; perhaps these trends would be found with a larger data set.
7. Diet and abundance of prey species would be beneficial in the investigation of future UMEs when harmful algal blooms are suspected to be the cause. Not only should the stomachs of marine mammals involved during the UME be thoroughly investigated, but also the stomachs of animals before and after the event should be analyzed as well.

Table 2.1. Stomachs for diet analysis were collected from the following bottlenose dolphin *Tursiops truncatus* strandings in the Northwest Florida Panhandle from Escambia to Wakulla Counties (n = 26). Stomachs were classified as "bloom" or "non-bloom" based on stranding dates during which *Karenia brevis* cell concentrations were higher than 100,000 cells/L of water. Stranding location was defined as either strandings inside (labeled "bay") or outside (labeled "coast") a bay or sound. Total length of the dolphin was a measured from the tip of the rostrum (upper jaw) to the fluke notch. Human interaction was either determined yes, no, or could not be determined (CBD) due to uncertainty or a limited exam due to decomposition.

Field #	Stranding date	Non-bloom/ Bloom	Location	Sex	Total Length (cm)	Human Interaction
FLCB110806-33	11/8/2006	Non-bloom	Choctawhatchee Bay	F	234.0	CBD
FLGM122206-34	12/22/2006	Non-bloom	Coast	F	249.0	Yes - bullet
PCNMFS07-01	1/5/2007	Non-bloom	Coast	M	262.5	Yes-fishing hook
PCNMFS07-02	1/7/2007	Non-bloom	Coast	M	269.0	CBD
FLCB021707-03	2/17/2007	Non-bloom	Choctawhatchee Bay	F	229.0	No
PCNMFS0705	2/21/2007	Non-bloom	Coast	M	174.4	No
PCNMFS07-07	3/9/2007	Non-bloom	Coast	M	230.5	No
PCNMFS07-10	3/26/2007	Non-bloom	St. Andrew Bay	M	247.0	Yes - propeller
PCNMFS07-11	6/24/2007	Non-bloom	Coast	M	237.5	CBD
PCNMFS07-12	7/27/2007	Non-bloom	Coast	F	243.5	CBD
FLCB102507-10	10/25/2007	Bloom	Choctawhatchee Bay	F	210.5	No
FLCB112207-12	11/22/2007	Bloom	Choctawhatchee Bay	F	242.0	No
PCNMFS07-13	11/29/2007	Bloom	Pensacola Bay	F	227.5	CBD
GUIS-NPS-07-04	12/2/2007	Bloom	Sound	M	280.0	Yes - entanglement
FLCB120307-14	12/4/2007	Bloom	Choctawhatchee Bay	M	197.5	CBD

Table 2.1 continued.

Field #	Stranding date	Non-bloom/ Bloom	Location	Sex	Total Length (cm)	Human Interaction
EAFB121907-01	12/19/2007	Bloom	Coast	M	139.0	CBD
FLCB122307-16	12/23/2007	Bloom	Choctawhatchee Bay	F	261.0	No
FLCB010208-01	1/2/2008	Bloom	Choctawhatchee Bay	F	237.0	No
FLCB010408-02	1/3/2008	Bloom	Choctawhatchee Bay	F	205.0	Yes - entanglement
FLPB011508-03	1/14/2008	Bloom	Pensacola Bay	M	229.0	No
PCNMFS08-01	2/8/2008	Bloom	Coast	F	253.0	No
FLCB020908-05	2/9/2008	Bloom	Choctawhatchee Bay	F	255.5	No
PCNMFS08-02	2/27/2008	Bloom	Sound	F	169.5	Yes - entanglement
PCNMFS08-03	3/10/2008	Bloom	Coast	M	305.0	CBD
FLSRS041208-06	4/21/2008	Bloom	Pensacola Bay	M	264.0	No
GW2009001D	3/01/2009	Non-bloom	St. Andrews Bay	F	243.0	CBD

Table 2.2. Total number of stomachs from bottlenose dolphins *Tursiops truncatus* collected from the Northwest Florida Panhandle distributed by stranding location and sex.

	Bay	Coast	Total
Females	11	3	14
Males	5	6	11
Total	16	9	25

Table 2.3. Total number of stomachs collected from bottlenose dolphins *Tursiops truncatus* from the Northwest Florida Panhandle distributed by location and bloom classification. Stomachs were classified as "bloom" or "non-bloom" based on stranding dates during and up to 6 months after *Karenia brevis* cell concentrations were higher than 100,000 cells/L of water.

	Non-bloom	Bloom	
	Nov 06 - July 07, Mar 09	Oct 07 - Mar 08	Total
Bay	4	12	16
Coast	7	2	9
Total	11	14	25

Table 2.4. Equations found in literature were used to calculate the fish length and weight from otoliths identified in stomachs of bottlenose dolphins *Tursiops truncatus* collected in the Northwest Florida Panhandle. TL is the total length of the fish (mm), OL is the otolith length (mm), WT is the fish weight (g), TOW is the otolith weight (g), and SL is the standard length of the fish (mm). Location is the study area where the fish used to generate the equations were collected. R is the coefficient of correlation for the equation.

Species	Equation	Location	R	Source
Brevoortia smithi	SL = 56.3 + 40.9(OL), Ln (WT) = -11.3 + 3.1 Ln (SL)	Indian River Lagoon, FL	0.71, 0.97	Barros, 1993
Anchoa mitchilli	SL = 12.1 + 21.4(OL), Ln (WT) = -11.7 + 3.1 Ln (SL)	Indian River Lagoon, FL	0.93, 0.85	Barros, 1993
Mugil cephalus	SL = -75.77125 + 36.85365 (OL), Ln (WT) = -12.2 + 3.3 Ln (SL),	Sarasota, FL; Indian River Lagoon, FL	0.98, 0.96	Barros and Wells, 1998; Barros, 1993
Orthopristis chrysoptera	SL = -40.97573 + 25.50623 (OL), Ln (WT) = -9.7 + 2.8 Ln (SL)	Sarasota, FL; Indian River Lagoon, FL	0.98, 0.99	Barros and Wells, 1998; Barros, 1993
Lagodon rhombiodes	SL = -19.31292 + 25.29199 (OL), Ln (WT) = -9.9 + 2.9 Ln (SL)	Sarasota, FL; Indian River Lagoon, FL	0.98, 0.95	Barros and Wells, 1998; Barros, 1993
Menticirrhus americanus	SL = -21.9 + 25.5(OL), Ln (WT) = -11.2 + 3.0 Ln (SL)	Indian River Lagoon, FL	0.99, 0.91	Barros, 1993
Micropogonias undulatus	TL = 277.14 (TOW) + 102.40, WT = 5.302x10^6 (TL)^3.134	Apalachicola Bay, FL; Northern Gulf of Mexico	0.93, 0.99	Bethea et al., 2006; Barger, 1985
Cynoscion nebulosus	SL = -31.5 + 20.8(OL), Ln (WT) = -11.5 + 3.2 Ln (SL)	Indian River Lagoon, FL	0.99, 0.95	Barros, 1993
Cynoscion regalis	SL = -10.3 + 17.9(OL), Ln (WT) = -10.7 + 2.9 Ln (SL)	Indian River Lagoon, FL	0.99, 0.93	Barros, 1993
Leiostomus xanthurus	SL = -32.7 + 28.2(OL), Ln (WT) = -11.5 + 3.2 Ln (SL)	Indian River Lagoon, FL	0.99, 0.97	Barros, 1993
Bairdiella chrysoura	TL = 453.77(TOW) + 88.07; WT = 0.18(TL)	Apalachicola Bay, FL; South Carolina	0.89, N/A	Bethea et al., 2006; Pate, 2008

Table 2.5. Stomach samples from bottlenose dolphins *Tursiops truncatus* that stranded in the Northwest Florida Panhandle were paired by stranding date, stranding location, then sex in that order to compare diet in the presence and absence of a *Karenia brevis* bloom. Stomachs were classified as "bloom" or "non-bloom" based on stranding dates during which *K. brevis* cell concentrations were higher than 100,000 cells/L of water. Stranding location was defined as either strandings inside (labeled "bay") or outside (labeled "coast") a bay or sound.

Bloom					Non-bloom				
Field #	Stranding date	Bay/ Coast	Sex	Total Length (cm)	Field #	Stranding date	Bay/ Coast	Sex	Total Length (cm)
FLCB102507-10	10/25/2007	Bay	F	210.5	FLCB110806-33	11/8/2006	Bay	F	234.0
PCNMFS07-13	11/29/2007	Bay	F	227.5	PCNMFS07-01	1/5/2007	Coast	M	262.5
FLCB122307-16	12/23/2007	Bay	F	261.0	FLGM122206-34	12/22/2006	Coast	F	249.0
FLCB010208-01	1/2/2008	Bay	F	237.0	PCNMFS07-02	1/7/2007	Coast	M	269.0
FLCB010408-02	1/3/2008	Bay	F	205.0	PCNMFS0705	2/21/2007	Coast	M	174.4
FLPB011508-03	1/14/2008	Bay	M	229.0	FLCB021707-03	2/17/2007	Bay	F	229.0
PCNMFS08-01	2/8/2008	Coast	F	253.0	GW2009001D	3/1/2009	Bay	F	243.0
FLCB020908-05	2/9/2008	Bay	F	255.5	PCNMFS07-07	3/9/2007	Coast	M	230.5
FLSRS041208-06	4/21/2008	Bay	M	264.0	PCNMFS07-10	3/26/2007	Bay	M	247.0

Table 2.6. Average stomach contents weight including standard deviation and ranges of bottlenose dolphins *Tursiops truncatus* from the Northwest Florida Panhandle. Weights are also included for bay, coast, non-bloom, bloom, female and male stranding stomachs. N is the number of stomachs used to calculate the average for each category. * or ** indicates Mann-Whitney p-values <0.05.

	n	Avg. Contents Weight ± Standard Deviation (g)	Stomach Contents Weight Range (g)
Total	25	298.73 ± 425.44	0 - 1465
Non-bloom	9	74.11 ± 215.25**	0 - 648
Bloom	9	332.42 ± 452.94**	0 - 1331
Bay	16	365.84 ± 461.97*	0 - 1465
Coast	9	119.77 ± 259.07*	0 - 648
Female	14	309.35 ± 425.44	0 - 1465
Male	11	283.39 ± 450.75	0 - 1331

Table 2.7. Frequency of occurrence, numerical abundance, and percent by mass for prey items were used to determine importance of prey. Prey species were identified in stomachs of bottlenose dolphins *Tursiops truncatus* (N = 25) collected from the Northwest Florida Panhandle. Bold numbers represent most frequent, abundant, or largest reconstructed mass of prey items. ~ = no data.

Prey	Common Name	Frequency (%)	Numerical (%)	Mass (%)
Loliginidae	squid	**27.3%**	**10.9%**	~
Penaeidae	penaeid shrimp	**31.8%**	2.6%	~
Clupeidae	herring	22.7%	1.8%	4.4%
Harengula jaguana	scaled sardine	9.1%	0.7%	~
Brevoortia patronus	gulf menhaden	4.6%	0.2%	~
Brevoortia smithi	yellow menhaden	9.1%	0.9%	4.4%
Engraulidae	anchovy	22.7%	0.4%	< 0.1%
Anchoa mitchilli	bay anchovy	9.1%	0.1%	< 0.1%
Anchoa hepsetus	striped anchovy	13.6%	0.3%	~
Arridae	catfish	9.1%	4.6%	~
Phycidae	hake	18.2%	1.7%	~
Urophycis floridana	southern hake	18.2%	1.7%	~
Mugilidae	mullet	22.7%	1.3%	5.1%
Mugil cephalus	striped mullet	22.3%	1.2%	5.1%
Syngnathidae	pipefish	4.6%	0.1%	~
Serranidae	sea bass	9.1%	< 0.1%	~
Hemanthias leptus	longtail bass	4.6%	< 0.1%	~
Lutjanidae	snapper	9.1%	< 0.1%	~
Haemulidae	grunts	22.7%	5.4%	5.9%
Orthopristis chrysoptera	pigfish	22.7%	5.2%	5.9%
Sparidae	porgy	**36.4%**	12.0%	17.0%
Stenotomus caprinus	longspine porgy	9.1%	1.0%	~
Lagodon rhomboides	pinfish	**36.4%**	**10.3%**	**17.0%**
Pagrus pagrus	red porgy	4.6%	0.1%	~
Sciaenidae	croaker	77.3%	43.3%	67.6%
Menticirrhus saxatilis	northern kingfish	9.1%	0.4%	~
Menticirrhus americanus	southern kingfish	9.1%	< 0.1%	< 0.1%
Menticirrhus littoralis	gulf kingfish	4.6%	< 0.1%	~
Menticirrhus spp.	kingfish spp.	9.1%	0.1%	~
Micropogonias undulatus	Atlantic croaker	**27.3%**	**8.5%**	**15.9%**
Cynoscion nebulosus	spotted seatrout	4.6%	< 0.1%	< 0.1%
Cynoscion arenarius	sand seatrout	4.6%	0.1%	~

Table 2.7 continued.

Prey	Common Name	Frequency (%)	Numerical (%)	Mass (%)
Cynoscion nothus	silver seatrout	4.6%	< 0.1%	~
Cynoscion regalis	weakfish	4.6%	< 0.1%	0.1%
Cynoscion spp.	seatrout spp.	**50.0%**	3.1%	~
Leiostomus xanthurus	spot	**54.6%**	**20.4%**	**41.9%**
Stellifer lanceolatus	star drum	4.6%	< 0.1%	~
Bairdiella chrysoura	silver perch	**31.8%**	5.3%	**9.7%**
Bairdiella sanctaeluciae	striped croaker	9.1%	1.2%	~
Stromateidae	butterfish	4.6%	0.1%	~
Peprilus alepidotus	harvestfish	4.6%	0.1%	~
Achiridae	sole	4.5%	< 0.1%	~
Trinectes maculatus	hogchoker	4.6%	< 0.1%	~
Cynoglossidae	tonguefish	4.5%	0.2%	~
Symphurus plagiusa	blackcheek tonguefish	4.6%	0.2%	~
Unknown Fish		86.4%	15.0%	~

Table 2.8. Average fish length and standard deviation calculated with equations from table 2.4 using lengths and widths of otoliths found in stomachs of bottlenose dolphins *Tursiops truncatus* along the Northwest Florida Panhandle. N is the total number of otoliths found in the stomachs with an otolith digestion rating of 0-2 and could be used for calculations. Fish lengths are reported in standard length with the exception of *Micropogonias undulatus* and *Bairdiella chrysoura*, which are in total length.

Prey	Common Name	n	Total Avg. fish length ± Standard Deviation (mm)
Brevoortia smithi	yellow menhaden	3	134.4 ± 4.6
Anchoa mitchilli	bay anchovy	1	49.3
Mugil cephalus	striped mullet	8	142.0 ± 14.8
Orthopristis chrysoptera	pigfish	5	143.5 ± 15.0
Lagodon rhomboides	pinfish	35	101.7 ± 21.8
Menticirrhus americanus	southern kingfish	1	113.5
Micropogonias undulatus	Atlantic croaker	63	140.9 ± 6.1
Cynoscion nebulosus	spotted seatrout	1	160.4
Cynoscion regalis	weakfish	3	136.5 ± 6.2
Leiostomus xanthurus	spot	212	126.0 ± 22.8
Bairdiella chrysoura	silver perch	63	102.2 ± 5.1

Table 2.9. Shannon Index of diversity for prey items found in stomachs of bottlenose dolphins *Tursiops truncatus* collected in the Northwest Florida Panhandle. Dolphin field ID number, length, stranding date, stranding location (bay or coast), stranding date in relation to *Karenia brevis* bloom, and sex are included.

Field number	Length (cm)	Stranding Date	Bloom/ Non-bloom	Bay/ Coast	Sex	Shannon Index
FLGM110806-33	234.0	11/8/2006	Non-bloom	Bay	Female	1.43
PCNMFS07-01	262.5	1/5/2007	Non-bloom	Coast	Male	1.79
PCNMFS07-02	269.0	1/7/2007	Non-bloom	Coast	Male	1.56
FLCB021707-03	229.0	2/17/2007	Non-bloom	Bay	Female	1.04
PCNMFS07-07	230.5	3/9/2007	Non-bloom	Coast	Male	0.9
PCNMFS07-10	247.0	3/26/2007	Non-bloom	Bay	Male	1.3
PCNMFS07-12	243.5	7/27/2007	Non-bloom	Coast	Female	1.95
FLCB102507-10	210.5	10/25/2007	Bloom	Bay	Female	0.58
FLCB112207-12	242.0	11/22/2007	Bloom	Bay	Female	1.27
PCNMFS07-13	227.5	11/29/2007	Bloom	Bay	Female	0.3
GUIS-NPS-07-04	280.0	12/2/2007	Bloom	Bay	Male	0.43
FLCB120407-14	197.5	12/4/2007	Bloom	Bay	Male	0.57
FLCB122307-16	261.0	12/23/2007	Bloom	Bay	Female	0.57
FLCB010308-01	237.0	1/2/2008	Bloom	Bay	Female	1.05
FLCB010308-02	205.0	1/3/2008	Bloom	Bay	Female	1
FLCB020908-05	255.5	2/9/2008	Bloom	Bay	Female	1.16
PCNMFS08-02	169.5	2/27/2008	Bloom	Bay	Female	0.3
FLSRS042108-06	264.0	4/21/2008	Bloom	Bay	Male	2.08
GW2009001D	242.6	3/1/2009	Non-bloom	Bay	Female	0.43

Table 2.10. Averages and standard deviations for prey length (mm) and percent decomposition were used to compare diet among bottlenose dolphins *Tursiops truncatus* from the Northwest Florida Panhandle. Stomachs were classified as "bloom" or "non-bloom" based on stranding dates during which *Karenia brevis* cell concentrations were higher than 100,000 cells/L of water. Stranding location was defined as either strandings inside (labeled "bay") or outside (labeled "coast") a bay or sound. The total number of prey items recovered from each stomach are in the column labeled "n."

Field number	Bay/ Coast	Non-bloom/ Bloom	Sex	n	Average length (mm)	Average % Decomposition
FLCB010308-01	Bay	Bloom	Female	151	47.09 ± 23.46	80.6 ± 14.8
FLCB010308-02	Bay	Bloom	Female	57	35.23 ± 15.14	81.3 ± 18.9
FLCB020908-05	Bay	Bloom	Female	28	32.16 ± 10.36	88.4 ± 4.3
FLCB102507-10	Bay	Bloom	Female	3	9.65 ± 0.21	50.0 ± 10.0
FLCB112207-12	Bay	Bloom	Female	1	2.5	10
FLCB120407-14	Bay	Bloom	Male	1	17	75
FLCB122307-16	Bay	Bloom	Female	4	8.70 ± 2.31	50.0 ± 20.0
FLSRS042108-06	Bay	Bloom	Male	62	88.16 ± 32.81	74.15 ± 11.67
PCNMFS07-13	Bay	Bloom	Female	18	8.91 ± 1.76	52.5 ± 12.4
PCNMFS08-02	Bay	Bloom	Female	3	10.42 ± 6.50	85.0 ± 0.0
PCNMFS07-02	Coast	Non-bloom	Male	53	33.79 ± 22.66	75.8 ± 20.9
PCNMFS07-07	Coast	Non-bloom	Male	4	9.11 ± 3.95	85.0 ± 0.0

Table 2.11. Numerical abundance were calculated on prey species identified in paired stomachs of bottlenose dolphins *Tursiops truncatus* that were collected from the Northwest Florida Panhandle (Table 2.5). Stomachs were classified as "bloom" or "non-bloom" based on stranding dates during which *K. brevis* cell concentrations were higher than 100,000 cells/L of water. Bold numbers represent most abundant prey items. The total number of prey items recovered from each stomach are in the column labeled "n."

		Non-Bloom		Bloom	
Prey	Common Name	n	Numerical (%)	n	Numerical (%)
Loliginidae	squid	33	**32.3%**	3	0.2%
Penaeidae	penaeid shrimp	1	< 0.1%	5	0.6%
Clupeidae	herring	4	1.9%	73	2.7%
Harengula jaguana	scaled sardine	2	0.1%	69	1.8%
Brevoortia smithi	yellowfin menhaden	2	1.8%	4	0.9%
Engraulidae	anchovy	2	0.1%	6	0.6%
Anchoa mitchilli	bay anchovy	2	0.1%	1	0.2%
Anchoa hepsetus	striped anchovy			5	0.4%
Phycidae	hake	7	4.1%	9	1.0%
Urophycis floridana	southern hake	7	4.1%	9	1.0%
Mugilidae	mullet	2	1.4%	46	2.2%
Mugil cephalus	striped mullet	2	1.4%	46	2.2%
Syngnathidae	pipefish			4	0.3%
Serranidae	sea bass			1	< 0.1%
Hemanthias leptus	longtail bass			1	< 0.1%
Lutjanidae	snapper			1	< 0.1%
Haemulidae	grunts	75	2.8%	35	11.8%
Orthopristis chrysoptera	pigfish	75	2.8%	35	**11.8**%
Sparidae	porgy	23	4.9%	81	11.8%
Stenotomus caprinus	longspine porgy	14	2.0%		
Lagodon rhomboides	pinfish	9	2.9%	75	**11.5**%
Pagrus pagrus	red porgy			6	0.3%
Sciaenidae	croaker	393	**36.2%**	748	**49.3%**
Menticirrhus saxatilis	northern kingfish	3	0.1%		
Menticirrhus americanus	southern kingfish	1	< 0.1%	2	0.1%
Menticirrhus littoralis	gulf kingfish	2	0.1%		
Menticirrhus spp.	kingfish spp.			5	0.3%
Micropogonias undulatus	Atlantic croaker	244	**11.4%**	3	0.5%

Table 2.11. continued.

Prey	Common Name	Non-boom n	Non-boom Numerical (%)	Bloom n	Bloom Numerical (%)
Cynoscion nebulosus	spotted seatrout			1	< 0.1%
Cynoscion arenarius	sand seatrout			1	0.2%
Cynoscion nothus	silver seatrout			2	0.1%
Cynoscion regalis	weakfish	3	0.1%		
Cynoscion spp.	seatrout spp.	27	3.4%	56	3.7%
Leiostomus xanthurus	spot	7	1.1%	510	**39.7**%
Stellifer lanceolatus	star drum	3	0.1%		
Bairdiella chrysoura	silver perch	91	**9.4%**	166	4.6%
Bairdiella sanctaeluciae	striped croaker	2	3.7%		
Achiridae	sole	1	< 0.1%		
Trinectes maculatus	hogchoker	1	< 0.1%		
Cynoglossidae	tonguefish	20	0.6%		
Symphurus plagiusa	blackcheek tonguefish	20	0.6%		
Unknown Fish		49	15.8%	118	19.4%

Table 2.12. Reconstructed percent by mass (%W) was calculated for species and families of prey identified in paired stomachs of bottlenose dolphins *Tursiops truncatus* that stranded before the *Karenia brevis* bloom (labeled "non-bloom") and strandings that occurred during and 6 months after the bloom (labeled "bloom"). Bold numbers represent the largest reconstructed mass of prey items.

Prey	Common Name	Non-bloom %W	Bloom %W
Clupeidae	herring	13.2%	
Brevoortia smithi	yellowfin menhaden	13.2%	
Engraulidae	anchovy	< 0.1%	< 0.1%
Anchoa mitchilli	bay anchovy	< 0.1%	< 0.1%
Mugilidae	mullet	13.7%	0.5%
Mugil cephalus	striped mullet	13.7%	0.5%
Sparidae	porgy	12.4%	5.1%
Lagodon rhomboides	pinfish	12.4%	5.1%
Sciaenidae	croaker	**60.6%**	**94.4%**
Menticirrhus americanus	southern kingfish	< 0.1%	
Micropogonias undulatus	Atlantic croaker	**29.3%**	0.1%
Cynoscion nebulosus	spotted seatrout		< 0.1%
Cynoscion regalis	weakfish	0.3%	
Leiostomus xanthurus	spot	7.5%	**88.0%**
Bairdiella chrysoura	silver perch	**23.5%**	6.3%

Table 2.13. Average fish length and standard deviation calculated with equations from literature using lengths and widths of otoliths collected from paired stomachs of bottlenose dolphins *Tursiops truncatus* collected before the *Karenia brevis* bloom (labeled "non-bloom") and stomachs collected during and 6 months after the bloom (labeled "bloom"). N is the total number of otoliths found in the stomachs with an otolith digestion rating of 0-2 and thus could be used for calculations. Fish lengths are reported in standard length with the exception of *Micropogonias undulatus* and *Bairdiella chrysoura*, which are in total length.

		Non-bloom		Bloom	
Prey	Common Name	n	Avg. length ± Standard Deviation (mm)	n	Avg. length ± Standard Deviation (mm)
Anchoa mitchilli	yellowfin menhaden			1	49.3
Mugil cephalus	striped mullet			1	149.8
Lagodon rhomboides	pinfish	1	52.52	5	81.7 ± 23.7
Menticirrhus americanus	southern kingfish	1	113.5		
Micropogonias undulatus	Atlantic croaker	62	141.0 ± 6.1		
Cynoscion regalis	weakfish	3	136.5 ± 6.2		
Leiostomus xanthurus	spot	4	118.3 ± 6.1	91	143.1 ± 25.3
Bairdiella chrysoura	silver perch	35	103.2 ± 3.0	25	99.7 ± 5.5

Table 2.14. Reconstructed percent by mass (%W) was calculated for species and families of prey identified in stomachs of bottlenose dolphins *Tursiops truncatus* that stranded inside a bay or sound and strandings that occurred along the coast of the Northwest Florida Panhandle. Bold numbers represent the largest reconstructed mass of prey items in the stomachs.

Prey	Common Name	Bay %W	Coast %W
Clupeidae	herring	0.7%	13.2%
Brevoortia smithi	yellowfin menhaden	0.7%	13.2%
Engraulidae	anchovy	< 0.1%	< 0.1%
Anchoa mitchilli	bay anchovy	< 0.1%	< 0.1%
Mugilidae	mullet	7.2%	
Mugil cephalus	striped mullet	7.2%	
Haemulidae	grunts	8.4%	
Orthopristis chrysoptera	pigfish	8.4%	
Sparidae	porgy	**20.9%**	7.6%
Lagodon rhomboides	pinfish	**20.9%**	7.6%
Sciaenidae	croaker	**62.8%**	**79.2%**
Menticirrhus americanus	southern kingfish	< 0.1%	< 0.1%
Micropogonias undulatus	Atlantic croaker	13.6%	**21.4%**
Cynoscion nebulosus	spotted seatrout	< 0.1%	
Cynoscion regalis	weakfish		0.3%
Leiostomus xanthurus	spot	**43.9%**	**37.1%**
Bairdiella chrysoura	silver perch	5.3%	**20.3%**

Table 2.15. Average fish length and standard deviation were calculated with equations from literature using otoliths collected from bottlenose dolphins *Tursiops truncatus* stomachs collected inside a bay or sound and stomachs collected along the coast of the Northwest Florida Panhandle. N is the total number of otoliths found in the stomachs with an otolith digestion rating of 0-2 and could be used for calculations. Fish lengths are reported in standard length with the exception of *Micropogonias undulatus* and *Bairdiella chrysoura*, which are in total length.

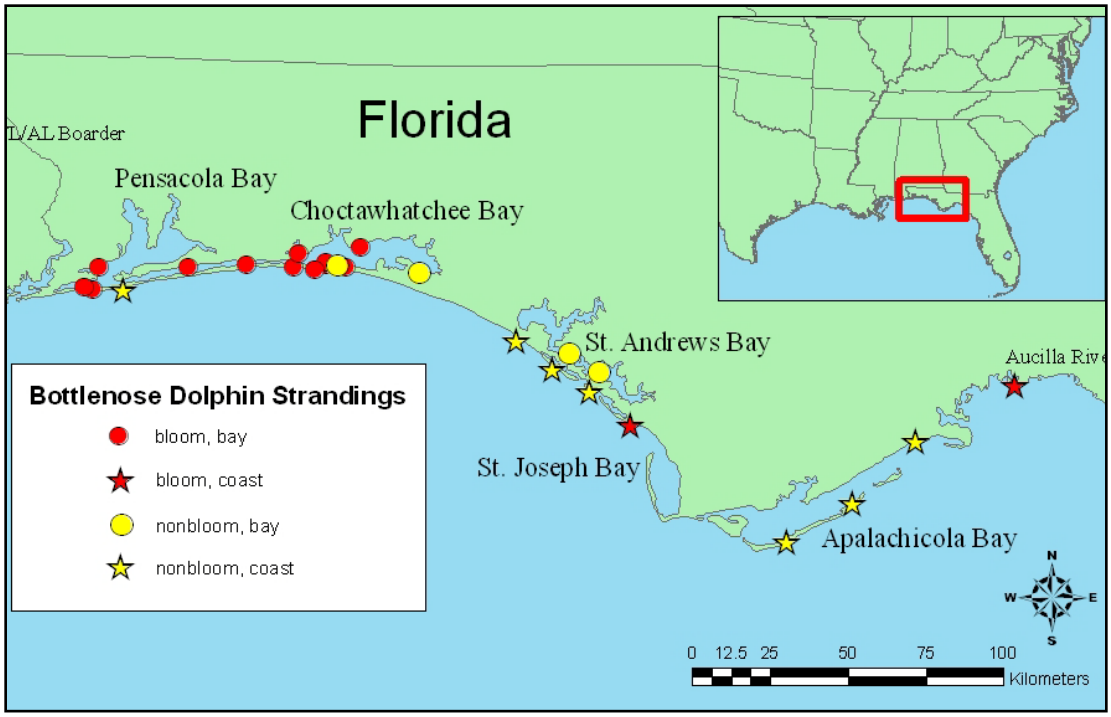
Prey	Common Name	n	Bay Avg. length ± Standard Deviation (mm)	n	Coast Avg. length ± Standard Deviation (mm)
Brevoortia smithi	yellowfin menhaden	3	134.4 ± 4.6		
Anchoa mitchilli	bay anchovy	1	49.3		
Mugil cephalus	striped mullet	8	142.0 ± 14.8		
Orthopristis chrysoptera	pigfish	5	143.5 ± 15.0		
Lagodon rhomboides	pinfish	34	103.2 ± 20.4	1	52.52
Menticirrhus americanus	southern kingfish			1	113.5
Micropogonias undulatus	Atlantic croaker			63	140.9 ± 6.1
Cynoscion nebulosus	spotted seatrout	1	160.4		
Cynoscion regalis	weakfish			3	136.5 ± 6.2
Leiostomus xanthurus	spot	207	126.3 ± 22.8	5	112.8 ± 6.1
Bairdiella chrysoura	silver perch	26	100.5 ± 6.7	37	103.4 ± 3.1

Table 2.16. Reconstructed percent by mass (%W) was calculated for species and families of prey identified in stomachs of female and male bottlenose dolphins *Tursiops truncatus* that stranded the Northwest Florida Panhandle. Bold numbers represent the largest reconstructed mass of prey items.

Prey	Common Name	Female %W	Male %W
Clupeidae	herring	0.9%	8.3%
Brevoortia smithi	yellowfin menhaden	0.9%	8.3%
Engraulidae	anchovy	< 0.1%	< 0.1%
Anchoa mitchilli	bay anchovy	< 0.1%	< 0.1%
Mugilidae	mullet	1.9%	8.6%
Mugil cephalus	striped mullet	1.9%	8.6%
Haemulidae	grunts	11.2%	
Orthopristis chrysoptera	pigfish	11.2%	
Sparidae	porgy	**17.8%**	**16.1%**
Lagodon rhomboides	pinfish	**17.8%**	**16.1%**
Sciaenidae	croaker	**68.2%**	**67.0%**
Menticirrhus americanus	southern kingfish	< 0.1%	< 0.1%
Micropogonias undulatus	Atlantic croaker	9.4%	**23.2%**
Cynoscion nebulosus	spotted seatrout	< 0.1%	
Cynoscion regalis	weakfish		0.2%
Leiostomus xanthurus	spot	**56.8%**	**25.1%**
Bairdiella chrysoura	silver perch	1.9%	**18.5%**

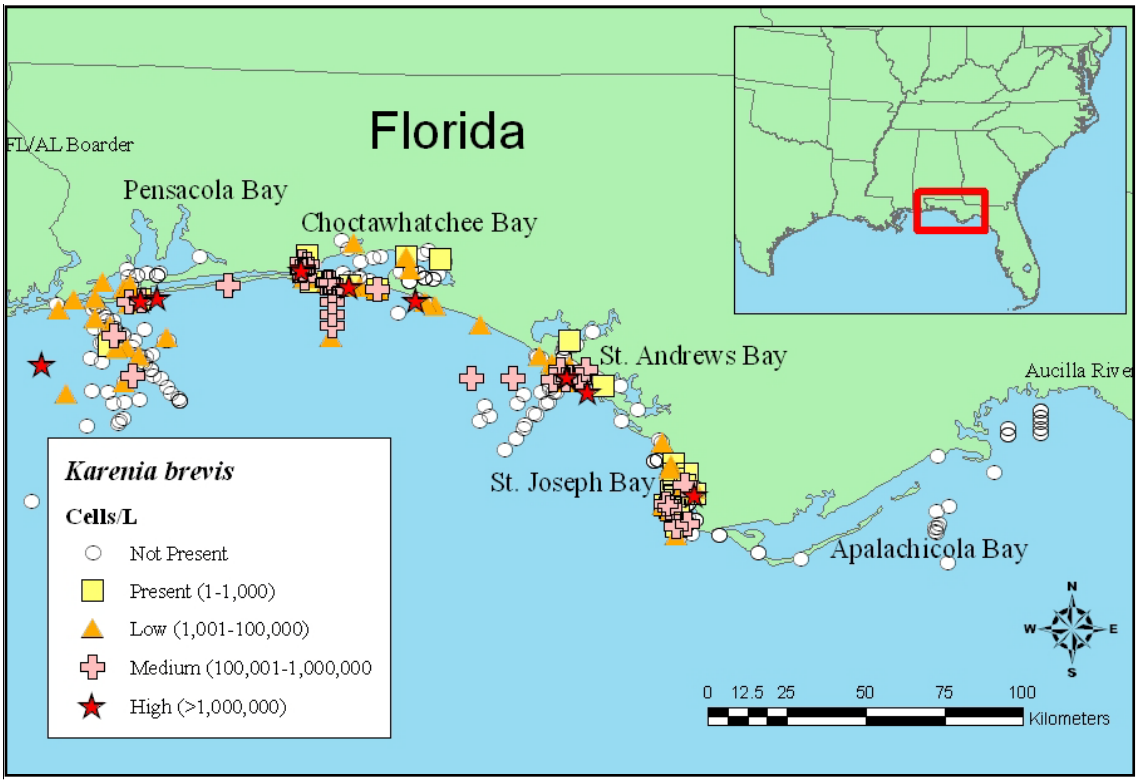
Table 2.17. Average fish length and standard deviation calculated with equations from literature using otoliths identified from female and male bottlenose dolphins *Tursiops truncatus* stomachs collected along the Northwest Florida Panhandle. N is the total number of otoliths found in the stomachs with an otolith digestion rating of 0-2 and could be used for calculations. Fish lengths are reported in standard length with the exception of *Micropogonias undulatus* and *Bairdiella chrysoura*, which are total length.

		Female		Male	
Prey	Common Name	n	Avg. length ± Standard Deviation (mm)	n	Avg. length ± Standard Deviation (mm)
Brevoortia smithi	yellowfin menhaden	3	134.4 ± 4.6		
Anchoa mitchilli	bay anchovy	1	49.3		
Mugil cephalus	striped mullet	8	142.0 ± 14.8		
Orthopristis chrysoptera	pigfish	5	143.5 ± 15.0		
Lagodon rhomboides	pinfish	26	111.5 ± 13.9	9	73.5 ± 14.6
Menticirrhus americanus	southern kingfish			1	113.5
Micropogonias undulatus	Atlantic croaker	1	134.6	62	141.0 ± 6.1
Cynoscion nebulosus	spotted seatrout	1	160.4		
Cynoscion regalis	weakfish			3	136.5 ± 6.2
Leiostomus xanthurus	spot	197	124.6 ± 22.2	15	143.3 ± 24.8
Bairdiella chrysoura	silver perch	5	107.9 ± 7.4	58	101.7 ± 4.6



Created by SRB 3/29/11 Projection: Florida Stateplane North (FIPS 0903)
Data Source: basemap: ESRI state layer, *Tursiops truncatus* stranding locations and stomachs: NOAA Marine Mammal Stranding Network

Figure 2.1. Map of bottlenose dolphins *Tursiops truncatus* strandings along the Northwest Florida Panhandle from Escambia to Wakulla Counties where stomachs were collected for diet analysis. Stomachs were classified as "bloom" or "non-bloom" based on dates during which *Karenia brevis* cell concentrations were higher than 100,000 cells/L of water and up to 6 months after elevated cell concentrations. Bay stomachs were classified as stomachs collected from standings inside an enclosed body of water; coast stomachs were from strandings outside any bays or sounds, along the Gulf of Mexico.



Created by SRB 3/29/11 Projection: Florida Stateplane North (FIPS 0903)
Data Source: basemap: ESRI state layer, *Karenia brevis* count and locations provided by FWRI

Figure 2.2. Map of *Karenia brevis* cells/L of water from the Florida Fish and Wildlife Research Institute (FWRI) Harmful Algal Bloom Monitoring Program (queried 30 April 2009). Water samples on this map were collected from November 2006 to April 2008 along the Northwest Florida Panhandle.

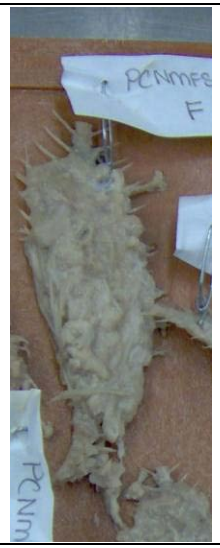
					
Percentage Range	1-10%	11-30%	31-50%	51-80%	81-100%
Description	Fish is whole, scales present, very little to no damage	Fish is whole with some digestion evidence present	Fish is partially whole, may be missing head or fins	Fish vertebrae present with flesh that is easily torn	Mostly only bones present with very little flesh

Figure 2.3. Whole or partial prey items found in stomachs of bottlenose dolphins *Tursiops truncatus* from the Northwest Florida Panhandle were rated based on percent of decomposition. Ranges of decomposition are presented with descriptions and photos. Spot photo credit: http://www.umes.edu/lmrcsc/Fish%20Reference%20Collection2.htm

Spot *Leiostomus xanthurus* otoliths						
Category	0	1	2	3	4	5
Description	Removed from skull	Found free in stomach, undamaged	Slight damage	Moderate damage	Heavy damage	Extreme damage

Figure 2.4. Classification of otolith digestion conditions using Recchia and Read (1989) scale for fish otoliths based on surface texture and shine, condition of edge lobulations, and degree of opacity. Photographs of spot *Leiostomus xanthurus* otoliths were used to visually represent the categories used to classify all fish otoliths found in the stomachs of bottlenose dolphins *Tursiops truncatus* from the Northwest Florida Panhandle.

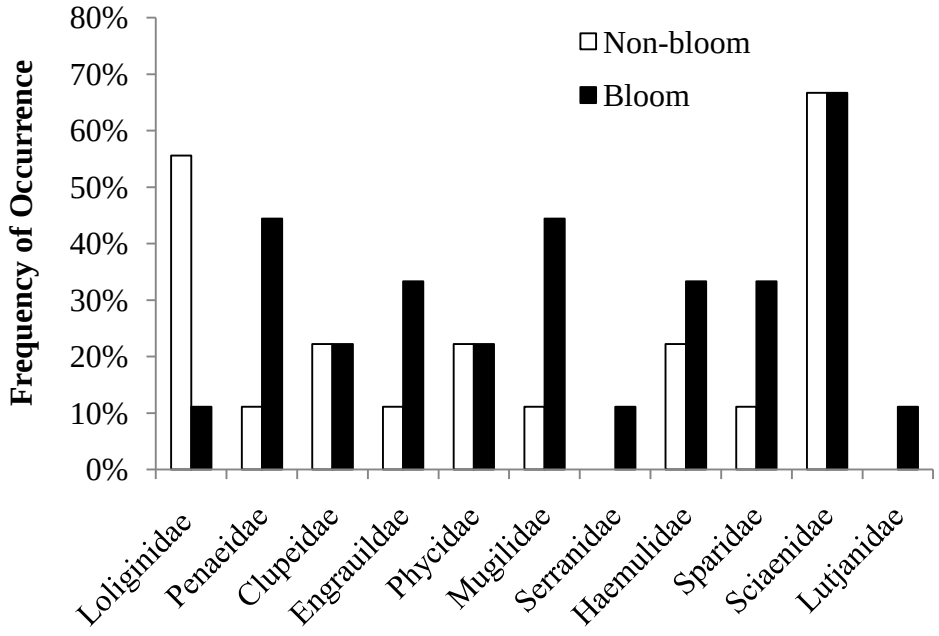
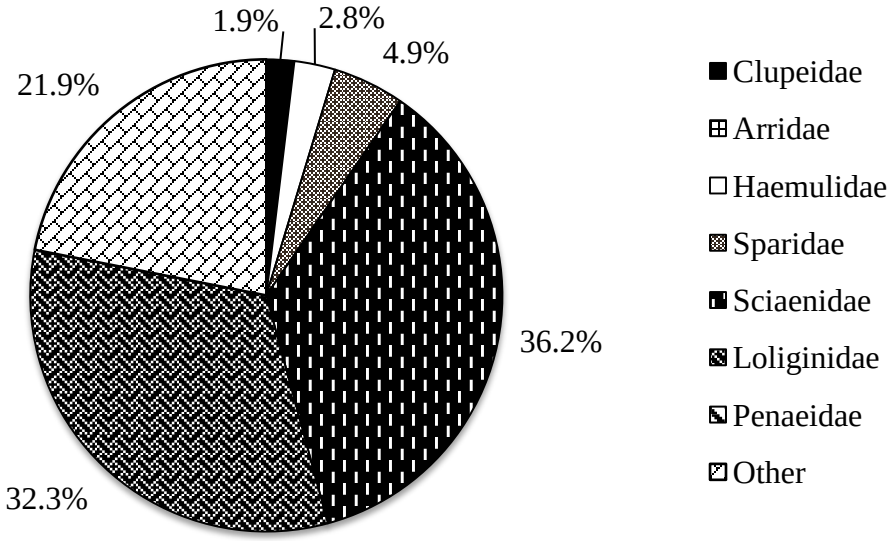


Figure 2.5. Frequency of occurrence (%) by family of prey found in paired stomachs from bottlenose dolphins *Tursiops truncatus* in the Northwest Florida Panhandle. White bars represent frequency of prey from stomachs that were collected in non-bloom periods (absence of *Karenia brevis*). Black bars are dolphin stomachs collected during *K. brevis* bloom periods (100,000 cells/L of water) and up to 6 months after.

a. Non-bloom (n = 9)



b. Bloom (n = 9)

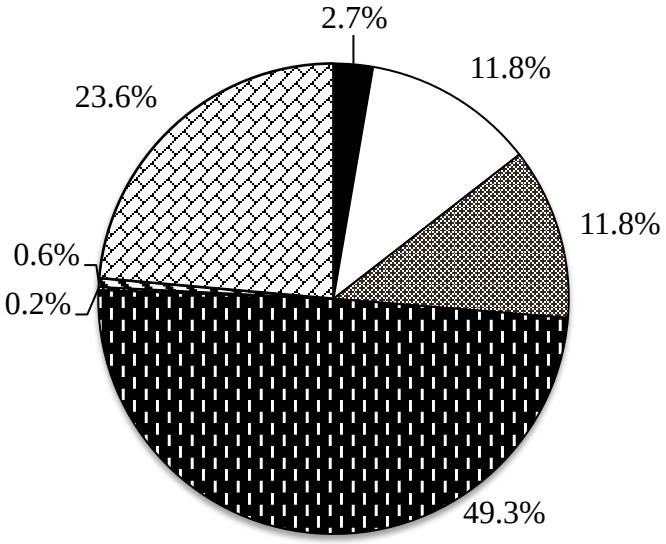
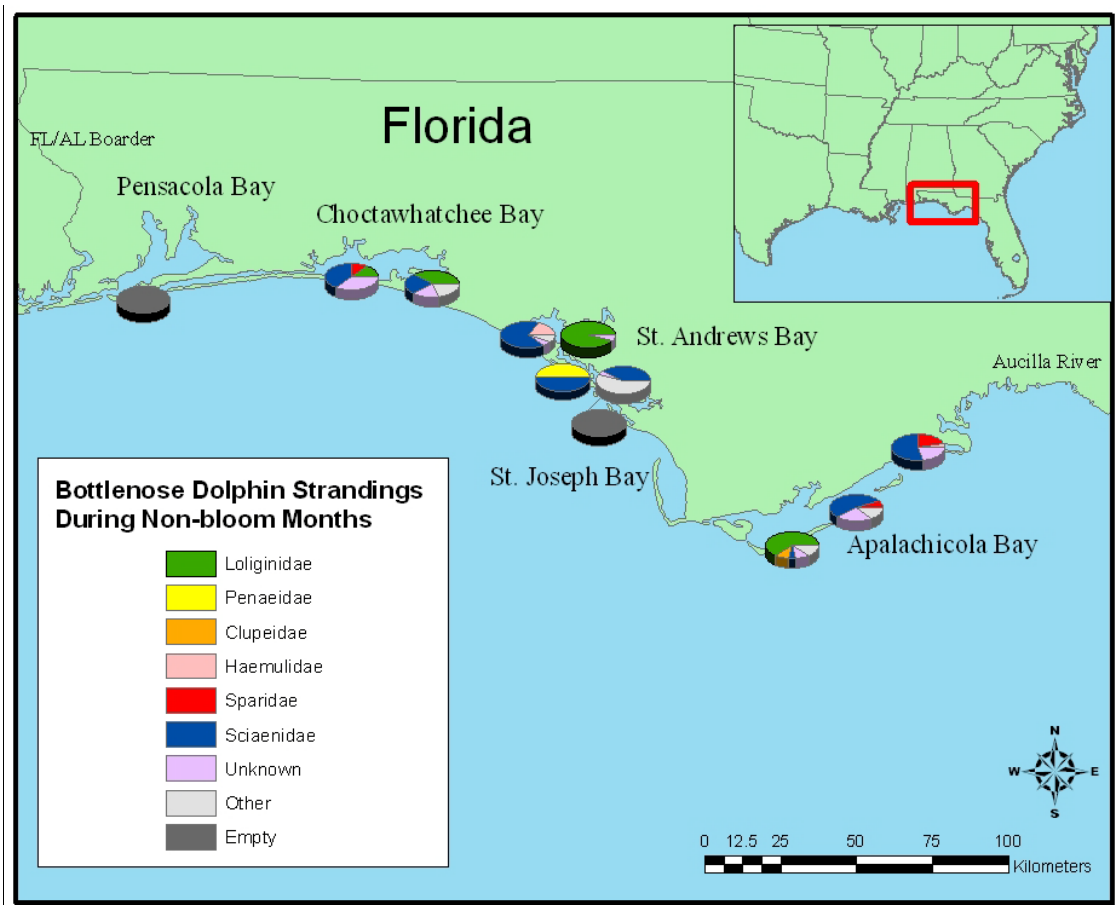
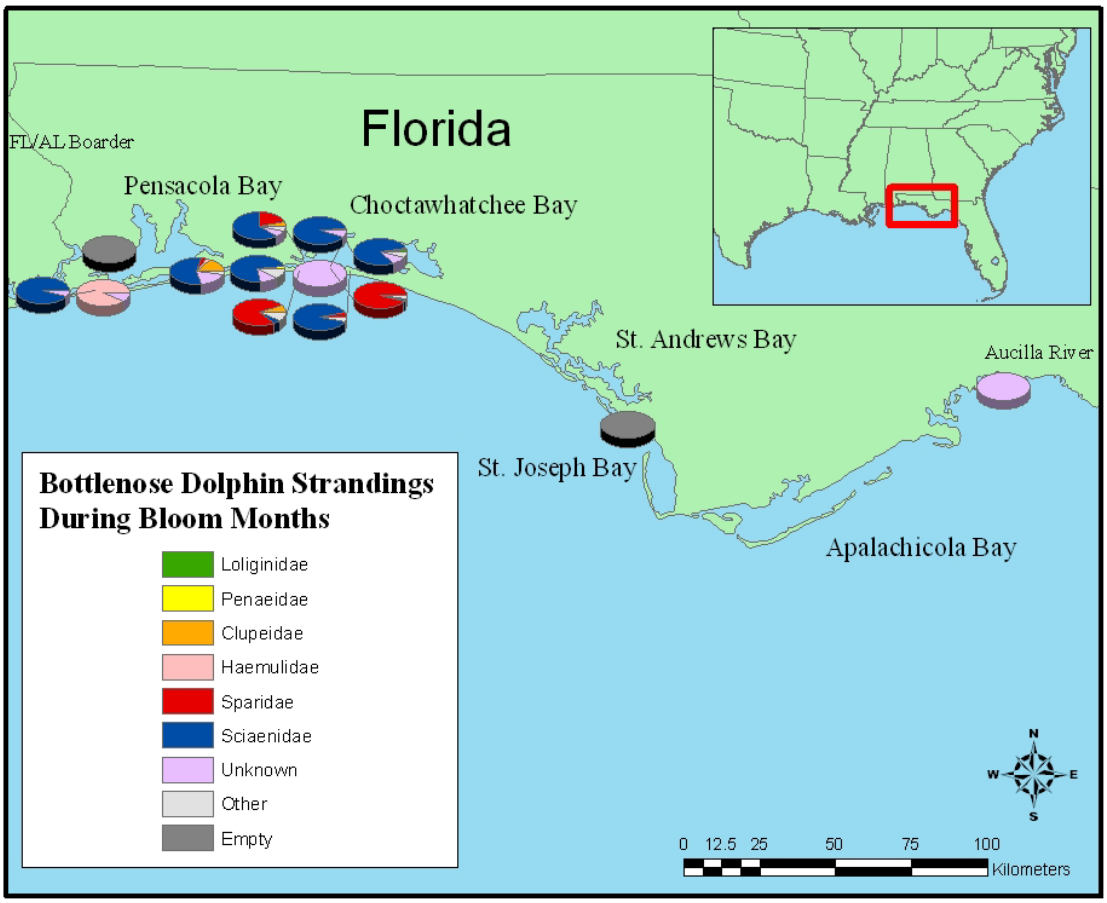


Figure 2.6. Prey family percentage by numerical abundance of paired stomachs from bottlenose dolphins *Tursiops truncatus* that stranded during a) non-bloom periods and b) bloom periods in the Northwest Florida Panhandle. Bloom periods were based on stranding dates during which *Karenia brevis* cell concentrations were higher than 100,000 cells/L of water and up to 6 months after (bloom) and periods with no blooms (non-bloom). Prey abundance of stomachs collected during non-bloom and bloom periods were significantly different ($\chi^2 = 203.23$; df = 13; $p < 0.001$).



Created by SRB 3/29/11 Projection: Florida Stateplane North (FIPS 0903)
Data Source: basemap: ESRI state layer, *Tursiops truncatus* stranding locations and stomachs: NOAA Marine Mammal Stranding Network

Figure 2.7. Map of pie charts representing prey family abundance of bottlenose dolphins *Tursiops truncatus* that stranded in the Northwest Florida Panhandle during non-bloom periods (absence of *Karenia brevis*).



Created by SRB 3/29/11 Projection: Florida Stateplane North (FIPS 0903)
Data Source: basemap: ESRI state layer, *Tursiops truncatus* stranding locations and stomachs: NOAA Marine Mammal Stranding Network

Figure 2.8. Map of pie charts representing prey family abundance of bottlenose dolphins *Tursiops truncatus* that stranded in the Northwest Florida Panhandle during bloom periods. Bloom periods were based on stranding dates during and 6 months after *Karenia brevis* cell concentrations were higher than 100,000 cells/L.

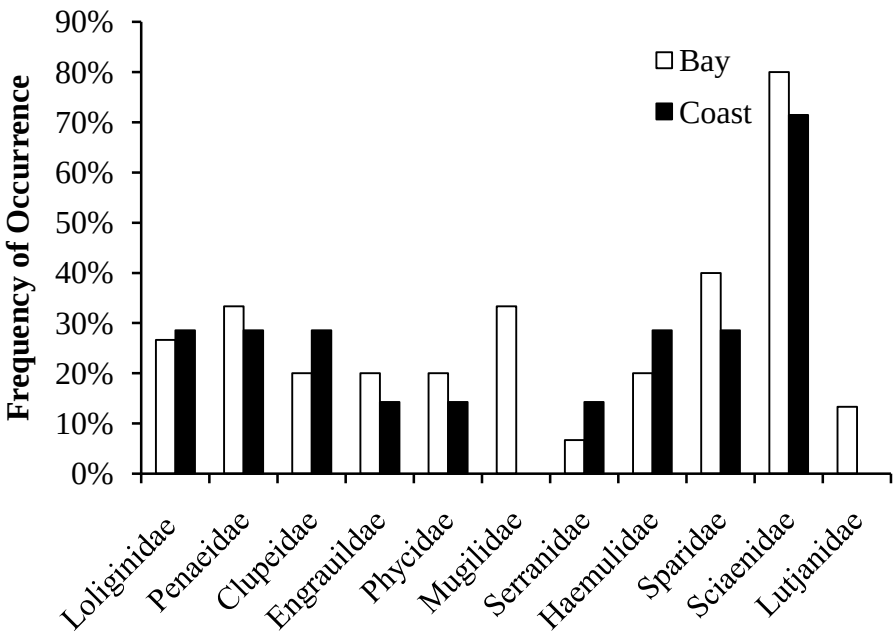
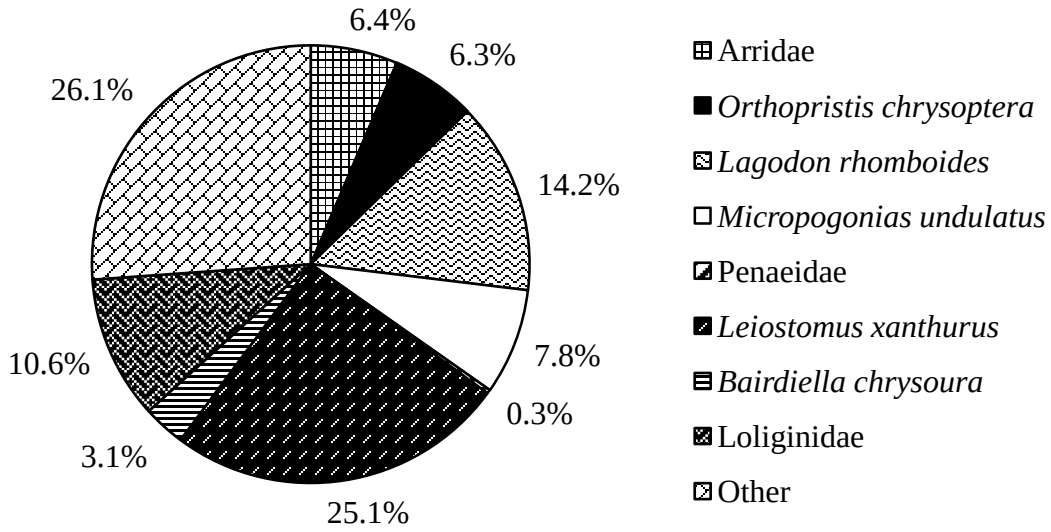


Figure 2.9. Frequency of occurrence (%) by prey family for bottlenose dolphins *Tursiops truncatus* that stranded inside bays or sounds (white bars) and strandings along the coast (black bars) of the Northwest Florida Panhandle.

a. Bay (n = 16)



b. Coast (n = 9)

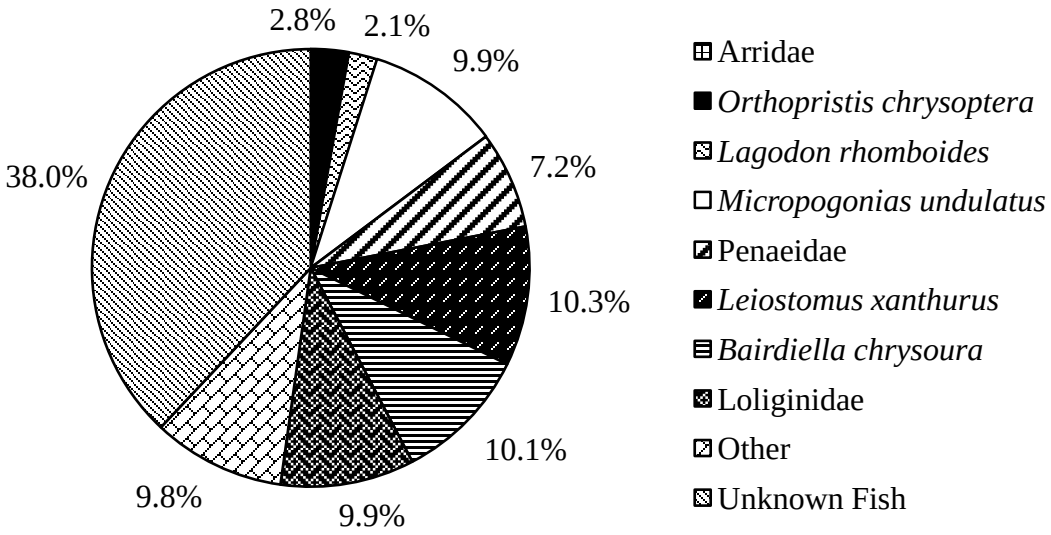


Figure 2.10. Prey species proportion by numerical abundance of stomach contents from bottlenose dolphins *Tursiops truncatus* that stranded a) inside bays and b) along the coast of the Northwest Florida Panhandle. Prey abundance of bay and coast stomachs were significantly different ($\chi^2 = 1052.17$; df = 34; $p < 0.001$).

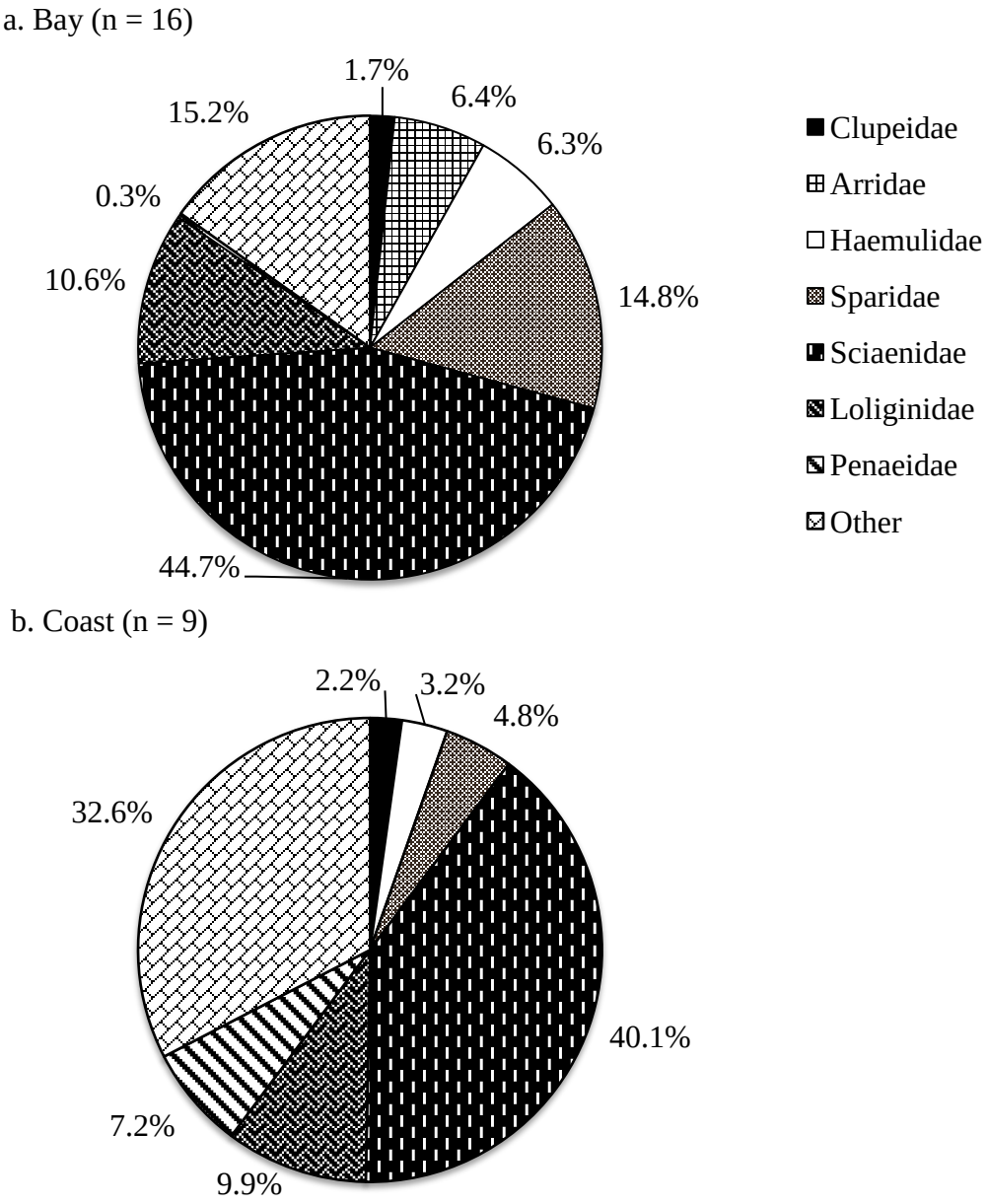


Figure 2.11. Prey family proportion by numerical abundance from stomach contents of bottlenose dolphins *Tursiops truncatus* that stranded a) inside bays and b) along the coast of the Northwest Florida Panhandle. Prey abundance of bay and coast stomachs were significantly different ($\chi^2 = 262.77$; df = 14; $p < 0.001$).

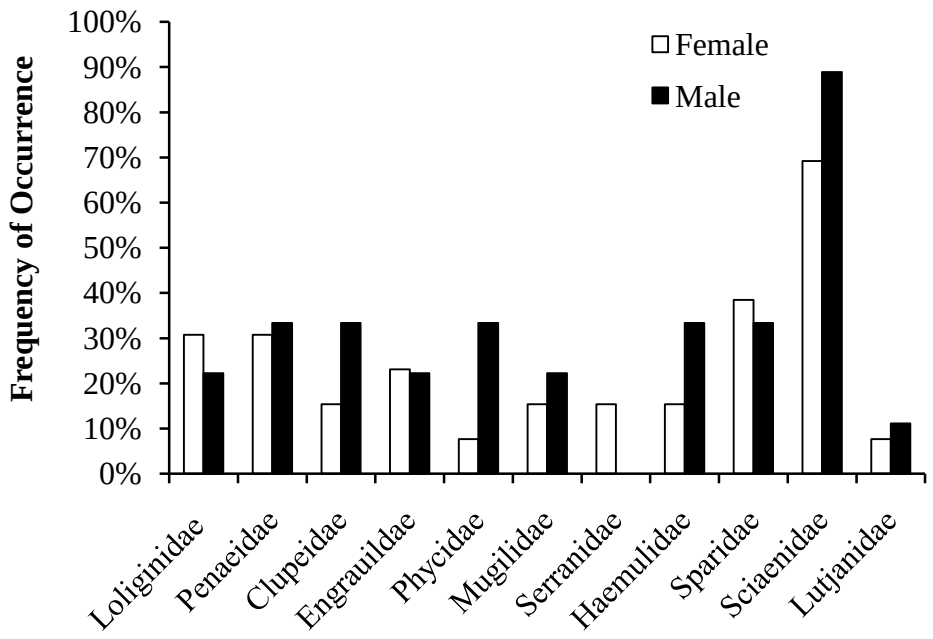
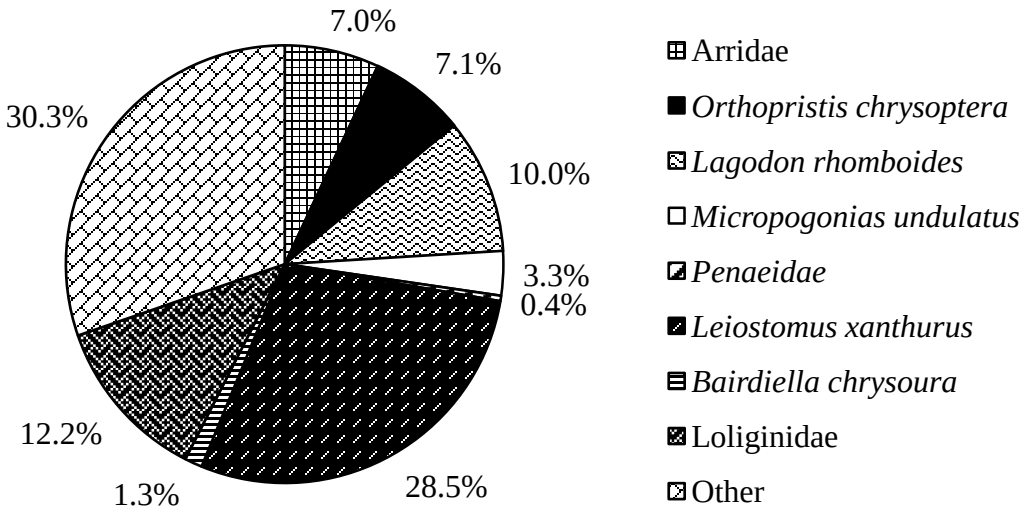


Figure 2.12. Frequency of occurrence (%) for prey families found in stomach contents of female (white bars) and male (black bars) bottlenose dolphins *Tursiops truncatus* along the Northwest Florida Panhandle.

a. Female (n = 14)



b. Male (n = 11)

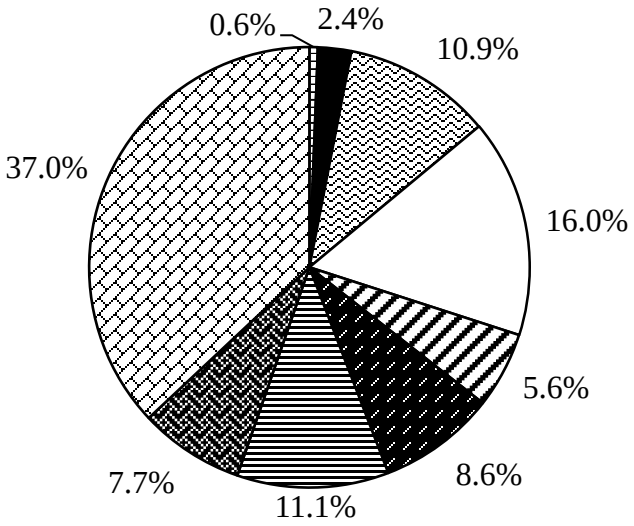
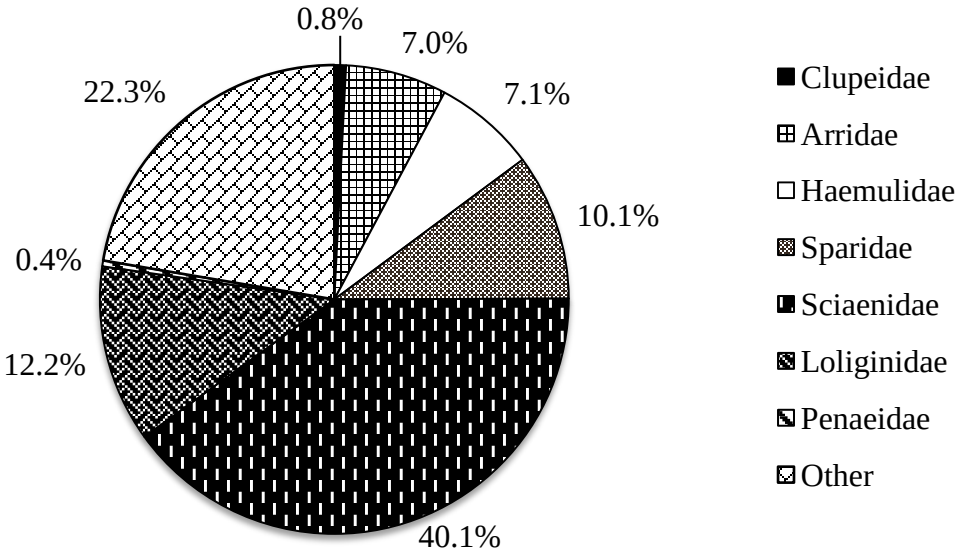


Figure 2.13. Prey species proportion by numerical abundance from stomach contents of a) female and b) male bottlenose dolphins *Tursiops truncatus* that stranded in the Northwest Florida Panhandle. Prey abundance between male and female stomachs were significantly different ($\chi^2 = 974.32$; df = 34; $p < 0.001$).

a. Female (n = 14)



b. Male (n = 11)

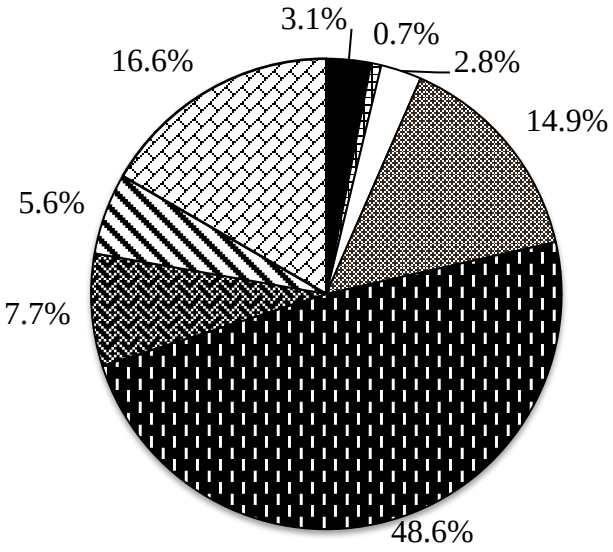


Figure 2.14. Prey family proportion by numerical abundance from stomach contents of a) female and b) male bottlenose dolphins *Tursiops truncatus* that stranded in the Northwest Florida Panhandle. Prey abundance between female and male stomachs were significantly different ($\chi^2 = 198.58$; df = 14; $p < 0.001$).

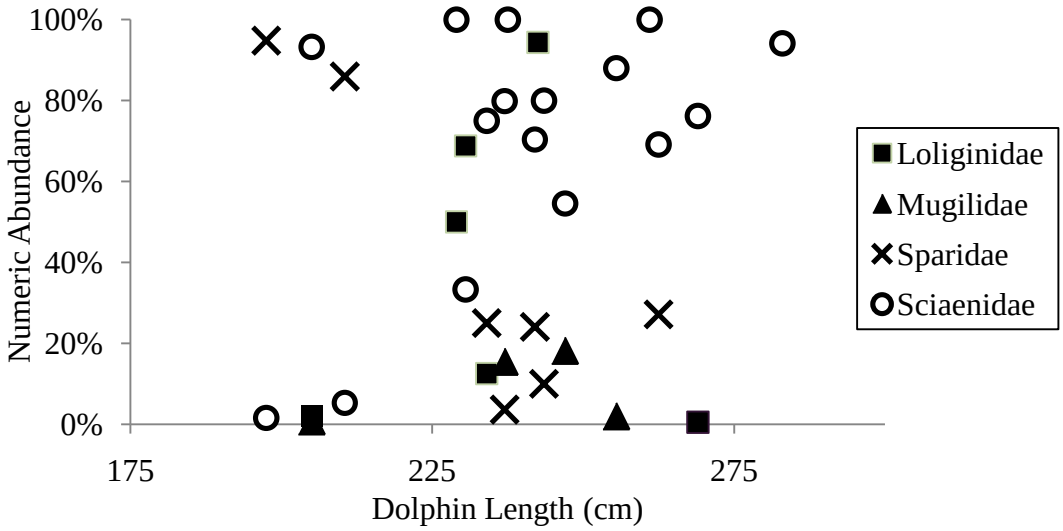


Figure 2.15. Percent by numeric abundance of 4 major prey families most frequently identified in stomachs from bottlenose dolphins *Tursiops truncatus* from the Northwest Florida Panhandle graphed by dolphin total length (cm).

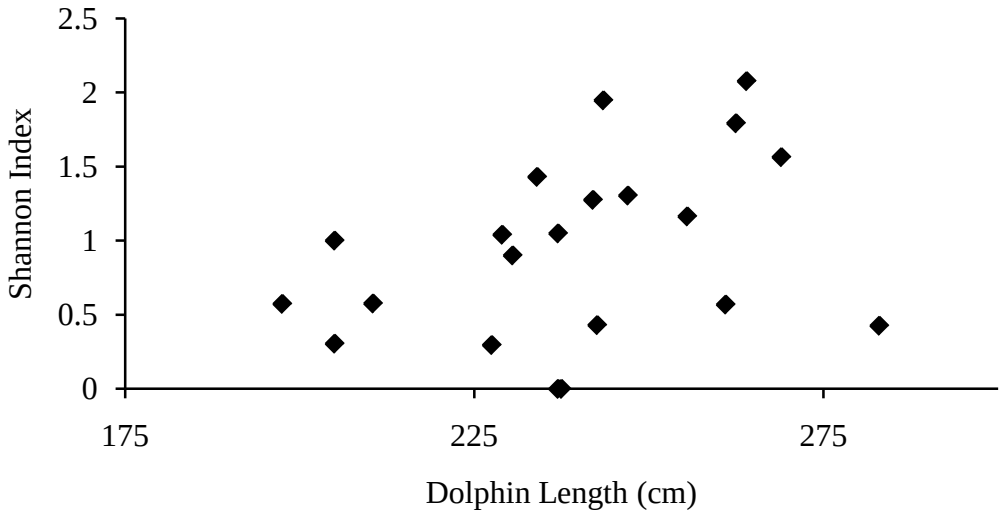


Figure 2.16. Shannon index values for prey diversity were calculated for bottlenose dolphins *Tursiops truncatus* from the Northwest Florida Panhandle and plotted by dolphin length (cm). Correlation between Shannon index values and dolphin length was not significant (Spearman = 0.4057, p = 0.0681, p = 0.361).

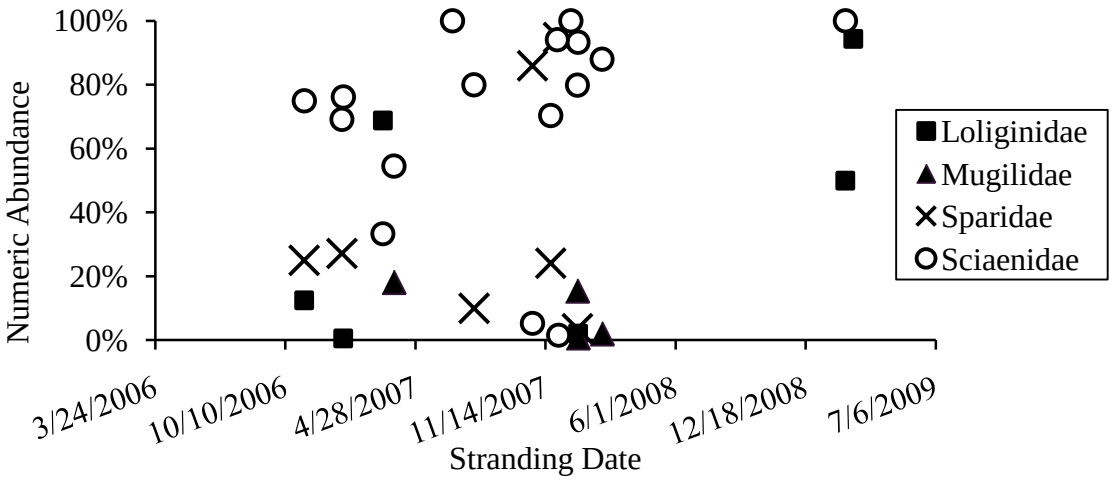


Figure 2.17. Numeric abundance of 4 major prey families found in stomachs collected from bottlenose dolphin *Tursiops truncatus* in the Northwest Florida Panhandle plotted by dolphin stranding date.

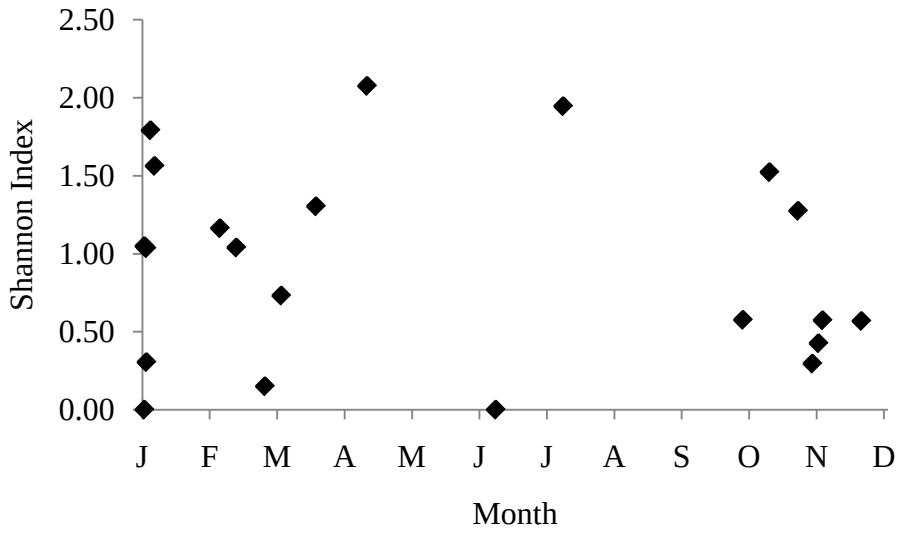


Figure 2.18. Shannon index values for prey diversity calculated for stomachs collected from bottlenose dolphins *Tursiops truncatus* in the Northwest Florida Panhandle from 2006 - 2009. The initial of each month during which the stranding took place is displayed on the x-axis.

CHAPTER 3

Foraging behaviors of bottlenose dolphins *Tursiops truncatus* near Savannah, Georgia

Abstract

Bottlenose dolphins *Tursiops truncatus* have a variety of foraging behaviors, and locations of foraging are often related to tides and habitat. The purpose of this study was to identify types of foraging behaviors of dolphins near Savannah, Georgia and determine which behaviors were related to tidal stage, creek width, depth, and group size. Surveys were conducted from south of the Savannah River to north Ossabaw Sound in Georgia from April 2009 to August 2009. The most frequently observed foraging behaviors were deep diving and begging occurring in 58 and 53 sightings, respectively. Using multivariate GAM analyses, foraging behaviors were found to be significantly correlated to group size, creek width, depth and time to low tide. Sightings with begging ($p < 0.001$), chasing ($p = 0.062$), and deep diving ($p = 0.037$) were significantly correlated with group size. Headstand ($p = 0.009$), hard stops ($p = 0.019$), chasing ($p = 0.004$), mudbank whacking ($p < 0.001$), herding/circling ($p = 0.024$), and strand feeding ($p = 0.006$) were correlated with shallow water or small creeks. Sightings with kerplunking ($p = 0.031$), mudbank whacking ($p = 0.001$), strand feeding ($p = 0.003$), and herding/circling ($p = 0.026$) were significantly correlated with low tide. Small tidal creeks, where a variety of behaviors are observed, have a lower water volume and

physical barriers which could be beneficial to the dolphin in capturing prey. Strand feeding was observed in 7 out of 242 sightings and occurred more frequently after low tide. Strand feeding events had group sizes of 1-4 dolphins observed on the mudbank, with 2 dolphins strand feeding more frequently. The results of this study were the first to characterize foraging behaviors in this area and investigate how bottlenose dolphins utilize the salt marsh estuary in terms of foraging.

Introduction

The bottlenose dolphin *Tursiops truncatus* has a variety of foraging behaviors, many of which are related to habitat, tidal stage, or human activities. Some of the foraging behaviors of dolphins include digging in the sediment for prey, herding prey, or create mud plumes to trap and capture prey (Rossbach and Herzing, 1997; Lewis and Schroeder, 2003; Gazda et al., 2005; Torres and Read, 2009). Mud ring feeding is a foraging behavior that is observed on shallow mud flats but not in the deeper portions of Florida Bay, Florida (Torres and Read, 2009). Other behaviors such as tail slapping against the shoreline and group circle swimming have only been observed at low tide in the May River, South Carolina (Rigley et al., 1981). Dolphins also foraging in association with human activities such as commercial and recreational fishing where dolphins feed on by-catch, discards, or bait (Leatherwood, 1975; Fertl and Leatherwood, 1997; Powell and Wells, 2011).

The behavior of prey can alter the foraging behavior of bottlenose dolphins (Connor et al., 2000b). For example, bottlenose dolphins in the Bahamas forage alone by digging in the sand for hidden prey (Rossbach and Herzing, 1997). Other fish such as

mullet spp. and menhaden spp. travel together in tight schools. To catch schooling prey, dolphins often work together. One of these cooperative behaviors is mud ring feeding in Florida Bay, FL (Torres and Read, 2009). This feeding behavior occurs in shallow water with mud bottom habitat where one dolphin forms a ring of stirred up mud surrounding a school of mullet (Torres and Read, 2009). Then as fish jump from inside the ring to the outside, a group of dolphins outside the ring captures the fish in mid-air (Torres and Read, 2009). Other types of cooperative foraging among bottlenose dolphins include herding and strand feeding (Rigley et al., 1981; Petricig, 1995; Gazda et al., 2005; Torres and Read, 2009).

Bottlenose dolphins are not equally distributed; instead, they tend to congregate and are more frequently observed at specific locations within an estuary (Würsig and Würsig, 1979; Ingram and Rogan, 2002; Mendes et al., 2002). These locations are often related to habitat characteristics and environmental variables such as tidal cycles (Ingram and Rogan, 2002; Mendes et al., 2002). Furthermore, prey of bottlenose dolphins in the southeast United States have distribution preferences related to habitat characteristics and environmental variables (Moser and Gerry, 1989; Peterson and Turner, 1994; Shervette et al., 2007). Distributions of dolphins are higher in areas with sharp changes in bottom topography such as channels, steep slopes, or rocks (Ingram and Rogan, 2002; Allen et al., 2001; Baumgartner et al., 2000; Würsig and Würsig, 1979). These features may also aid dolphins in catching prey. For instance, channels have wall barriers that dolphins may use to herd and trap fish. In the Shannon estuary, Ireland, larger group sizes and a greater frequency of dolphins were observed near areas with deeper water depths and steep bottom slopes than in areas with depths less than 30 m and with slopes (maximum

difference in depth in a specified area) less than 22 m (Ingram and Rogan, 2002). Additionally, dolphins found in areas with deep water and steep bottom slopes were observed consuming Atlantic salmon *Salmo salar*, garfish *Belone belone*, and European eels *Anguilla anguilla* (Ingram, 2000).

Some coastal populations of bottlenose dolphins move with tidal fluctuations that could be due to prey distribution (Würsig and Würsig, 1979; Shane, 1980; Gregory and Rowden, 2001). Bottlenose dolphins observed in the Gulf of San José, Argentina were found moving to deeper water during intermediate flood tides (Würsig and Würsig, 1979). Thermal fronts and tidal eddies are formed due to the bottom topography and tidal influence in the Gulf of San José (Gagliardini et al., 2004). These fronts and eddies can have a positive effect on primary production in the Gulf and thus may be related to the distribution of dolphins and their prey (Gagliardini et al., 2004). The Kessock Channel of Moray Firth, Northeast Scotland experiences tidal intrusion fronts that attract or stall adult salmon while traveling to spawning grounds (Mendes et al., 2002). A higher abundance of dolphins were observed during these intrusion fronts along the Kessock Channel indicating dolphins were reacting to tidal influences on prey (Mendes et al., 2002).

The inshore waterways near Savannah, Georgia have a 2.1 m semi-diurnal tidal amplitude (NOAA.gov, accessed October 19, 2009). A majority of the estuarine habitat consists of salt marsh with branching creeks. Many of the smaller creeks are nearly depleted of water twice per day at low tide. The tidal cycle of the estuaries of Georgia would likely influence dolphin foraging behaviors, which has yet to be studied in this area.

Several types of foraging behavior of bottlenose dolphins have been studied in South Carolina and described around mid-coastal Georgia. Rigley et al. (1981) observed three types of foraging behavior for bottlenose dolphins near Bluffton, South Carolina: tail slapping, circle swimming bouts, and beaching. Tail slapping was described only during low tides when one dolphin would travel parallel to a mudbank and repeatedly tail slap for about 5-10 meters herding fish against the bank (Rigley et al., 1981). Circling was observed with groups of 2-3 dolphins that swam in the same direction creating a tight circle to concentrate fish (Rigley et al., 1981). During low tides, the circling behavior was commonly followed by beaching, also known as strand feeding, where the dolphins created a surge wave to beach themselves and fish on exposed mudbanks (Rigley et al., 1981; Petricig, 1995). The dolphins could then easily consume fish stranded on the mudbanks (Rigley et al., 1981; Petricig, 1995). Similar feeding strategies to strand feeding, where dolphins intentionally beached themselves, have been reported in the northern Gulf of Mexico, the Gulf of California, and Sado estuary in Portugal (Leatherwood, 1975; dos Santos and Lacerda, 1987; Mullin, 1988; Silber and Fertl, 1995). Beach hunting behavior observed in Shark Bay, Australia is similar to strand feeding in that dolphins intentionally beach themselves (Sargeant et al., 2005). However, beach hunting has the following differences to strand feeding: beach hunting is not a group behavior; it occurs on shallow beaches facing open waters; and the dolphin fed on single prey items (Petricig, 1995; Sargeant, et al., 2005; Duffy-Echevarria et al., 2008). Strand feeding, as reported in South Carolina, is a group behavior with 1-5 individuals that occurs day and night when mudbanks are exposed during low tide (Petricig, 1995; Duffy-Echevarria et al., 2008). This behavior was first published from observations in

Duplin River near Doboy Sound in Georgia (Hoese, 1971). To date, the characteristics of strand feeding have also been reported in studies from Bull Creek, South Carolina (Petricig, 1995; Duffy-Echevarria et al., 2008). The relationship of strand feeding to environmental variables have yet to be determined, and no studies on strand feeding have been published in the coastal estuaries of Georgia from south of the Savannah River to north of Ossabaw Sound.

The purpose of this research was to collect an inventory of the types and prevalence of foraging behaviors of bottlenose dolphins in the inshore waters near Savannah, Georgia. The hypothesis was tested that some of these behaviors would be related to temperature, salinity, tidal state, creek width, depth, and dolphin group size. Lastly, habitat of strand feeding behavior near Savannah, Georgia was investigated, and some of the resident dolphins that strand feed were identified.

Methods

Rivers, creeks, and sounds were surveyed from south of the Savannah River (approximately 32.06°N) to northern Ossabaw Sound (approximately 31.80°N) along transects (Figure 3.1). Surveys started in April 2009 and ended in August 2009. Effort was made to survey each transect twice a month striving for equal spatial effort during low tide on a 6.7 m Boston Whaler with a 2 stroke engine. Surveys were conducted with boat speeds between 33-41 km/hr and in waters with a Beaufort Sea State of 3 or less. The number of personnel on the boat ranged from 3-5 people with 2 photographers, 1-2 data recorder(s), and a boat operator.

When dolphins were sighted, the location, estimation of group size, group activity, environmental conditions (time, depth, water temperature, salinity, creek width), and photographs of dorsal fins were collected (Table 3.1). Group activity was rated in order of most predominant to least and included: travel, feed (fish observed in mouth), probable feed, play, rest, social, with boat, unknown, and other. Survey tracks, sighting locations, and foraging event locations were recorded using a Garmin GPS Map 76. A group was defined as dolphins within a 100 m circular radius (modified from Urian and Wells, 1996). The time to low tide for dolphin sightings were determined using the nearest station on the NOAA tide chart (Figure 3.2; NOAA.gov, accessed June 9, 2010). A negative time value (min) indicated the sighting was before low tide, whereas a positive time value (min) indicated the time of the sighting was after low tide. Depth was collected at the beginning of the sighting once the boat was positioned about 15 m from dolphins or where the dolphins were first observed using a Garmin GPSMAP® 168 Sounder. Temperature and salinity were measured 1 m from the water surface at the end of each sighting using a YSI® Y30 SCT Meter. Creek width was determined in the field using a Bushnell® Yardage Pro Sport® 450 laser range finder. To determine widths of larger rivers that could not be measured in the field, estimates were made with ArcGIS 9.3. The study area basemap was created with files from ESRI and the USGS National Hydrography Dataset which were projected to Georgia Stateplane East (FIPS 1001). Photographs were taken with Cannon EOS 40D and Nikon D90 digital cameras with 70-400 mm or 70-300 mm zoom lenses, respectively. Photographers strived to obtain photos of all the dolphins in each sighting.

Dolphins were followed for up to 3 hours when foraging behavior was observed or when it was 2 hours before or after low tide. During all follows, incidents of foraging behaviors were recorded and categorized as the following:

Deep diving: Dolphin(s) performed all of the following actions: lifted tail flukes out of the water; dove for long periods (> 1min); surfaced at random with no clear directional pattern (*i.e.*, surface intervals were not in a straight line); and surfaced successively less than 100 m apart.

Chase: Dolphin(s) made unpredictable quick movements (1-2 s). Often the dolphin's body moved in a side to side motion similar to a shark or snake.

Kerplunk: Dolphin lifted flukes out of the water and then thrust flukes down quickly into the water, which created a "kerplunk" sound and a 1-2 m high splash (Nowacek, 1999; Connor et al., 2000a).

Leap kerplunk: Dolphin jumped out of the water followed by a kerplunk as the dolphin returned to the water.

Mudbank whack: Dolphin traveled at the water surface within 1 m of the shore and the dolphins' ventral surface faced the shore. The dolphin's flukes thrusted toward the shore and created a large splash (Figure 3.3a).

Headstand: Dolphin was vertical in the water column with the flukes out of the water. The dolphin held this position for a time of at least 2 seconds. Often, water around the dolphin was stirred up with mud (Figure 3.3b).

Hard stop: Dolphin traveled about 1 m from shore at a slow speed (estimate 1-2 m s^{-1}); then, the dolphin raised its caudal peduncle out of the water and kept its fluke underwater. This behavior caused an immediate stop in the forward movement of the dolphin. Often, the water around the dolphin was stirred up with mud (Figure 3.3c).

Herding/circling: A group of dolphins traveled within 1 m of each other and suddenly increased speed (estimate 3-5 m s^{-1}) in the same direction or in circles.

Strand feeding: Dolphin(s) created a wave that temporarily stranded the dolphin(s) and fish on the mudbank.

Begging: Dolphin(s) approached within 10 m of the boat with head-up and chin out of the water in the direction of the boat, or dolphin(s) surfaced within 2 m of the boat with the ventral surface of the body facing the boat (modified from Samuels and Bejder, 2004; Finn et al., 2008).

Shrimp scavenge: Dolphin(s) fed from discarded fish by-catch from a shrimp vessel. By-catch was not directed toward the dolphin as it was tossed from the vessel.

Crab pot: Dolphin took a deep dive near a crab pot buoy. Buoy was then observed submerged underwater or moved side to side in a way that was not attributed to waves or wind.

Provisioning: Dolphin(s) were illegally fed by a human. Differentiated from shrimp scavenge by the human display of the food to the dolphin before he/she tossed the food toward the dolphin's mouth.

When foraging behavioral events occurred, the location, time, pictures (when possible), and behavior details were recorded (Table 3.1). For strand feeding events, pictures, creek width, time, location, and number of dolphins on the mudbank were recorded (Table 3.1). To account for bias of behaviors observed during low tide, the numbers of behavioral events within the first 5 minutes of sightings were used to compare behavior frequency. The amount of time spent looking for dolphins and time spent following dolphins were separated into intervals. Time intervals were 1 hour each, and a negative interval indicated the effort/follow was before low tide; whereas a positive interval indicated the effort/follow was after low tide (Table 3.2). The distribution of time in these intervals was used to display effort among the tidal cycle.

Multivariate Generalized Additive Models (GAMs) were used to investigate relationships of foraging behaviors with group size, temperature, salinity, water depth, creek width, and time to low tide using SAS 9.1.3 software (SAS Institute Inc., 2007). The presence or absence of each type of foraging behavior observed throughout the entire sighting was used in the multivariate GAMs. Only foraging behaviors that were observed in 5 or more sightings were used in GAM analysis. Accurate depths could not be collected for sightings where the dolphins were close to the creek edge; thus, 0 m depth was used for GAM analysis. Creek widths could not be determined for sightings inside Wassaw Sound; thus, the width of the sound opening (3700 m) was used for all sightings within the sound for GAM analysis. For sightings with strand feeding, the average creek width of each strand feeding event was used.

Photographs of strand feeding events were used to identify dolphins, confirm the number of dolphins on the mudbank, and identify prey. All photographs from the field

were downloaded and edited with the computer program ACDSee. Photographs of dorsal fins of dolpins in each sighting were rated on a quality scale, ranging from 1-3, based on focus/clarity, camera angle to the dolphin, contrast, and the proportion of fin present (Urian et al., 1999; Friday et al., 2000). The distinctiveness of each dolphin fin ranged from 1 (fins with a large notch or several smaller notches) to 3 (fins that were clean without any notches; Urian et al., 1999). Only photos with quality and distinctive rating levels of 1 and 2 were used to create a photo-identification catalog. All catalogued individuals during sightings with strand feeding were compared to photographs of dolphins' dorsal fins collected as the dolphins returned to the water to identify which dolphins were strand feeding. Often, body scars and notches on pectoral fins were used as additional identifiers. The identification of individuals was used to determine how many dolphins out of all catalogued dolphins photographed in 2009 were observed strand feeding. Identification was also used to determine how many days each individual was observed strand feeding. Photographs of strand feeding events were also used to identify prey.

Results

A total of 242 dolphin sightings were recorded, and 212 dolphins were catalogued on 47 days from April 16, 2009 to August 4, 2009. Total time on effort searching for dolphins was almost even among time intervals to low tide with the exception of the large amount of effort one hour before low tide (Figure 3.4). After dolphins were sighted, more time was spent following dolphins during low tide to optimize chances of observing

strand feeding (Figure 3.5). A total of 118 sightings were observed before low tide, and 124 sightings were after low tide (Figure 3.6). The maximum number of dolphins estimated within a sighting was 41, and the minimum was 1. The majority of sightings had group sizes of 3-5 dolphins (Figure 3.7). Water depth at sightings ranged from 0 m (sightings at creek edge) to 19.8 m, and the average depth was 5.6 ± 3.6 m (Figure 3.8). Creek widths for sightings ranged from 3-950 m, with 22 sightings observed in Wassaw Sound (Figure 3.9). Salinity ranged from 14.4-34.3‰ with an average of 27.3 ± 4.2‰, and water temperatures ranged from 19.1-31.6°C with an average of 28.7 ± 2.2°C for all sightings.

Foraging behaviors were observed during 197 of the 242 dolphin sightings. A total of 458 foraging events were recorded (Table 3.3). The most common behavior was deep diving, which was observed in 58 sightings (Table 3.3). Deep diving dolphins were spread out and difficult to follow in the field; thus, the number of deep diving events for each sighting could not be accurately counted. Begging was observed in 53 sightings, and begging was the most frequently observed foraging event accounting for 32% of all foraging events (146/458; Table 3.3). Mudbank whacking was the third most observed behavior in terms of sightings (20/197 sightings with foraging), and it was also the third most frequent foraging event (44 events; Table 3.3). Dolphins were observed kerplunking in 12 sightings and 24 events (Table 3.3). Hard stop and chasing were both observed in 10 sightings and 28 events (Table 3.3). Dolphins were observed foraging with headstands, herding/circling, and strand feeding in only 7 sightings each (Table 3.3). Strand feeding was observed in only 7 sightings; however, 131 strand feeding events were recorded (Table 3.3). Shrimp scavenge, crab pot interactions, provisioning, and

leap kerplunking were the least frequently observed behaviors in terms of number of sightings and number of events (Table 3.3).

The number of events within the first five minutes of the sighting were compared among foraging behavior types (Table 3.3). Begging was the most frequent behavior, occurring in 35 sightings within the first 5 minutes (Table 3.3). Mudbank whacking and kerplunking occurred in 5 sightings in the first 5 minutes (Table 3.3). Strand feeding, chasing, shrimp scavenging, and crab pot interactions were observed within the first 5 minutes for 3 sightings each (Table 3.3). Headstands and hard stops occurred in 2 sightings each; while leap kerplunking, herding/circling, and provisioning happened within the first 5 minutes of one sighting each (Table 3.3).

Dolphins begged throughout the study area and in various creek widths (Figure 3.10). Shrimp scavenging occurred in two locations where shrimp vessels were docked: Lazaretto Creek and Thunderbolt (Figure 3.10). Humans illegally fed dolphins at Lazaretto Creek from the docks where the majority of shrimp scavenging also occurred (Figure 3.10). The majority of sightings with deep diving occurred throughout the study area in the sounds and large rivers (Figures 3.11 and 3.12). The 2 sightings with 11 leap kerplunk events occurred on the same day in southern Wassaw Sound. Sightings with herding/circling occurred near smaller creeks (Figures 3.12 and 3.13). Chase, headstand, and hard stop occurred in sightings within or near small creeks (Figure 3.11). Dolphins kerplunking were spread thoughout the study area (Figure 3.13). Three sightings with strand feeding were first observed in large creeks, but the dolphins were followed into smaller creeks where strand feeding events took place (Figures 3.12 and 3.13). Strand feeding events were in areas with small tidal creeks (Figure 3.14). Sightings with

mudbank whacking and strand feeding occurred more frequently in or near areas with smaller creeks (Figure 3.13).

A significant correlation for sightings with begging, chasing, and deep diving to group size were determined using multivariate GAMs (Figures 3.15-3.17). Begging was significantly correlated with mid-to large-group sizes (*i.e.*, 8 or more dolphins, $p < 0.001$; Figure 3.15). Sightings with chase behaviors had a higher occurrence with dolphin group sizes of 6-10 dolphins ($p = 0.062$; Figure 3.16). Deep diving was also significantly correlated with smaller to mid group sizes (*i.e.*, 3-12 dolphins, $p = 0.037$; Figure 3.17).

Sightings with kerplunks were correlated with salinity and temperature; while sightings with begging and deep diving were correlated with salinity but not temperature (Figures 3.15, 3.17, and 3.18). Begging ($p = 0.021$) was correlated with mid-range salinity values (Figure 3.15). Deep diving was positively correlated with higher salinities but not correlated with any other salinity range ($p = 0.012$; Figure 3.17). Sightings with kerplunks were correlated with mid and high range salinities ($p = 0.021$) as well as low and high temperatures ($p = 0.046$; Figure 3.18).

Signficant correlations were found with multivariate GAM analysis for water depths and sightings with chase, deep diving, headstands, hard stops, and mudbank whacking (Figures 3.16-3.17 and 3.19-3.21). Sightings with chasing ($p = 0.004$), headstands ($p = 0.008$), and hard stops ($p = 0.019$) were all significantly correlated with shallow water in depths near 2 m (Figures 3.16, 3.19, and 3.20). Deep diving was positively correlated with mid-range water depths (3-11 m) and negatively correlated with shallow depths (< 3 m, $p = 0.036$; Figure 3.17). Mudbank whacking was correlated with shallow (creek edge-3 m) and deeper depths (> 11 m, $p = 0.001$; Figure 3.21).

Significant correlations were found among creek width and sightings with behaviors of deep diving and herding/circling using multivariate GAM analysis (Figures 3.17 and 3.22). Sightings with deep diving were positively correlated with larger creek widths and negatively correlated with narrow creeks ($p < 0.001$; Figure 3.17). Herding/circling was significantly correlated with smaller creek widths ($p = 0.024$; Figure 3.22).

Sightings with kerplunking, mudbank whacking, and herding/circling were significantly correlated with time to low tide ($p = 0.001$, 0.026, and 0.031 respectively; Figures 3.18, 3.21, and 3.22). Sightings with kerplunking were correlated with tidal stage, around 100 minutes before and after low tide ($p = 0.03$; Figure 3.18). Mudbank whacking was observed in sightings that occurred 100 minutes before and 200 minutes after low tide ($p = 0.001$; Figure 3.21). Sightings with herding/circling happened 100 minutes before and 150 minutes after low tide ($p = 0.026$; Figure 3.22).

Mudbank whacks, kerplunks and begging were observed frequently with other foraging behaviors in dolphin sightings rather than as the only foraging behavior of the sighting (Table 3.4). Sightings where dolphins were observed mudbank whacking also had strand feeding, herding/circling, kerplunks, hard stops, headstands, chasing, deep diving, and begging (Table 3.4). Dolphin sightings with kerplunk foraging behavior also had mudbank whacking, hard stops, headstands, chasing, begging, deep diving, crab pot interactions, leap kerplunks, herding/circling, and strand feeding (Table 3.4). Begging occurred in sightings with deep diving, mudbank whacking, interactions with crab pots, shrimp scavenging, provisioning, kerplunks, herding/circling, and strand feeding (Table

3.4). Sightings of strand feeding were most often observed with mudbank whacking, herding/circling, and begging (Table 3.4).

Strand feeding occurred on 7 different days with a total of 131 strand feeding events (Table 3.3). Dolphin sightings with strand feeding were not correlated with sighting group size ($p = 0.380$), salinity ($p = 0.425$), temperature ($p = 0.167$), or depth ($p = 0.215$) according to Multivariate GAM analysis (Figure 3.23). However, sightings with strand feeding were significantly correlated with smaller creek widths ($p = 0.006$) and low tide ($p = 0.003$; Figure 3.23). Dolphins strand fed in creeks with an average width of 48.6 ± 39.8 m and strand feeding occurred in many of the smaller creeks thoughout the study area (Figure 3.14). Sightings with strand feeding were correlated with time to low tide ($p < 0.003$; Figure 3.23). The timing of strand feeding events occurred more frequently after low tide as water levels were rising. A total of 12 strand feeding events were observed before low tide, whereas 119 events occurred up to 3 hours after low tide.

Group sizes of 1-4 dolphins were observed strand feeding on the mudbanks, with pairs of dolphins strand feeding more frequently (77 out of 130 events; Table 3.5). Pairs of strand feeding dolphins were also observed in all 7 sightings with strand feeding (Table 3.5). A total of 11 dolphins out of 212 cataloged individuals for the summer of 2009 were photographed strand feeding. A total of 4 dolphins were observed strand feeding on 2 separate days. Only 1 dolphin was identified strand feeding on 3 out of the 7 days strand feeding was observed.

Prey were photographed in 59 out of 131 events with strand feeding. Mullet spp. were identified most frequently in 37 out of the 59 events with prey photographed. During 1 event, a Bothidae was identified in the mouth of a single strand feeding dolphin.

The remander of the strand feeding events with photographed prey were unfocused or at a bad angle and identification could not be determined.

Discussion

The most important findings of this thesis are the identification of previously unknown foraging behaviors of dolphins near Savannah, Georgia; how dolphins utilize the salt marsh habitat in Georgia in terms of foraging, and how strand feeding behavior near Savannah Georgia is different from strand feeding near Bluffton, South Carolina. Kerplunking, crab pot interactions, provisioning, shrimp scavenging, mudbank whacking, and strand feeding are foraging behaviors that are reported in the estuaries near Savannah, GA for the first time. Additional details are provided regarding mudbank whacking and strand feeding that were absent in other studies. Descriptions are provided on behaviors such as headstand, hard stops, and leap kerplunks, which are similar to foraging behaviors of dolphins described in other areas. Foraging behaviors such as headstands, hard stops, herding/circling, and strand feeding occur in the small creeks whereas other behaviors such as deep diving occur throughout the area. The foraging behaviors of bottlenose dolphins near Savannah, Georgia are related to human activities, tidal cycle, salinity, temperature, creek width, and depth. Some dolphins may utilize the high prey density and lower water volume at low tide and in narrow creeks to increase foraging efficiency as some behaviors are positively correlated to low tide, narrow creeks, and shallow depths. Lastly, this study demonstrates that not all strand feeding

behavior is similar and that dolphins in estuaries within 25 km from each other may utilize this behavior in different ways.

Several of the foraging behaviors observed in this study have also been reported in other studies on bottlenose dolphins. These behaviors include: deep diving, strand feeding, mudbank whacking, kerplunk, chasing, herding, crab pot interactions, provisioning, shrimp scavenging, and begging (Hoese, 1971; Leatherwood, 1975; Rigley et al., 1981; Nowacek, 1999; Connor et al., 2000a; Noke and Odell, 2002; Samuels and Bejder, 2004; Cunningham-Smith et al., 2006; Finn et al., 2008). Kerplunks had been described in Shark Bay, Australia and Florida (Nowacek, 1999; Connor et al., 2000a). Six sightings of bottlenose dolphins in a 3 year study from the Bahamas had herding and circling behavior during which 79 events occurred (Rossbach, 1999). Tail slapping was observed for a total of 7 times during a 6 month study on dolphins in South Carolina (Rigley et al., 1981). Mudbank whacking near Savannah was similar to descriptions of tail slapping; however, Rigley et al. (1981) did not describe dolphins swimming on their side or the large wave that was observed with mudbank whacking. In addition, Rigley et al. (1981) described fish herded toward the shore; this was not observed during the mudbank whacking events in this study.

Behaviors such as leap kerplunking, headstands and hard stops are similar to behaviors like lunging and bottom grubbing/root (Leatherwood, 1975; Rossbach and Herzing, 1997; Nowacek, 2002). Dolphins in many locations have been observed porpoising or lunging out of the water towards fish at the surface (Leatherwood, 1975). This behavior is similar to the two sightings with leap kerplunking in this study. The difference from leaping was that at end of the jump the dolphin would kerplunk, which

may be used to stun prey. On one occasion shortly after and near a leap kerplunk event, an unresponsive fish was observed floating on the surface. Within seconds, a dolphin approached and captured the fish. Bottom grubbing is a foraging behavior observed in the clear waters near Grand Bahama Island, Bahamas (Rossbach and Herzing, 1997). Rossbach and Herzing (1997) observed dolphins orienting themselves toward the seafloor and digging through the sand sediment with their rostrum. This is also similar to root behavior observed in Sarasota, Florida (Nowacek, 2002). In this study, it could not be determined if the dolphins rostrum was in the sediment due to the high turbidity of the water. However, mud plumes were observed immediately after a headstand or hard stop, indicating that the dolphins may have been bottom grubbing/rooting.

Foraging behaviors associated with human commercial/recreational fishing and recreational activities, such as tourism, have been reported in various locations worldwide (Gunter, 1942; Gunter, 1954; Norris and Prescott, 1961; Lockyer, 1987; Noke and Odell, 2002; Samuels and Bejder, 2004; Cunningham-Smith et al., 2006). Dolphins risk entanglement, injury, and ingestion of contaminated prey when they interact with fishing gear, consume discards, or ingest food from human provisioning (Wells and Scott, 1994; Samuels and Bejder, 2004; Wells et al., 2008). Sightings with begging were correlated with group size. Larger group sizes of bottlenose dolphins interacting with human activities have been reported in other studies (Chilvers and Corkeron, 2001; Speakman et al., 2006). In Moreton Bay, Australia and Charleston, South Carolina, groups of dolphins that interacted with shrimp trawlers had larger group sizes than dolphins that did not interact with trawlers (Chilvers and Corkerson, 2001; Speakman et al., 2006). The shrimp fishery has the largest amount of by-catch of all fisheries, and

discarding this fish by-catch provides a large amount of potential prey for dolphins (Alverson et al., 1994). The high frequency of begging behavior and large group sizes correlated with begging in this area may have harmful implications for local populations of bottlenose dolphins.

Another behavior in this study that was correlated with group size was deep diving (group sizes of 3-15). This is similar to the mean group size of 12 reported for deep diving in Florida Bay (Torres and Read, 2009). Significant correlations between foraging behavior and dolphin group size reported in this study are similar to observations from sightings in other areas.

Foraging behaviors that were correlated with salinity may be related to prey distribution or sampling bias. Distribution and abundance of fish are often related to salinity (Moser and Gerry, 1989; Lankford and Targett, 1994). Fish are more likely to occur in habitats that promote growth. The optimal salinity for growth of juvenile weakfish *Cynoscion regalis* was determined to be 20‰ (Lankford and Targett, 1994). This is the same salinity where foraging behaviors of bottlenose dolphins in Barataria Bay, Louisiana were reported (Miller and Baltz, 2003). The salinity correlation among deep diving and kerplunking could be associated with salinity preferences among fish species. According to GAM analysis, begging was correlated with salinity; however, there is no biological explanation for this correlation as sightings with begging were dispersed throughout the study site and begging was not correlated with tidal stage. The salinity of sightings were not evenly distributed throughout the 2009 and because begging was one of the most observed foraging behaviors, the correlation may be inaccurate.

Further information fish distribution in terms of salinity ranges near Savannah, Georgia are needed to investigate this further.

Hard stops, headstands, chasing, mudbank whacking, and herding/circling were all correlated with either shallow water or narrow creeks. Less water volume and the physical barriers of smaller creeks could benefit dolphins with capturing prey as the time to capture prey in a smaller area would be less than the time to capture the same prey in a larger area. Chase behavior in Florida Bay, which is an open shallow water bay with mudflats, was observed between 1-2 m depth, and it was correlated with waters less than 4 m in this study (Figure 3.16; Torres and Read, 2009). The occurrence of this behavior in shallow water may increase success at chasing prey due to less water volume and the physical barrier of the creek bottom. Herding/circling, headstand, and hard stops are other foraging behaviors where the habitat of small creeks likely increases chances of catching prey.

Bottlenose dolphins in Georgia have several foraging behaviors related to the tidal cycle. Mudbank whacking, kerplunking, strand feeding, and herding/circling were correlated with low tides, which could be due to less water volume during this tidal stage. Mudbank whacking, herding/circling, and strand feeding behaviors were reported only occurring during low tide in South Carolina as well (Rigley et al., 1981; Petricig, 1995). Fish, such as spot *Leiostomus xanthurus* and pinfish *Lagodon rhombiodes*, are likely near the creek edge during this time as the water has yet to flood the marsh (Peterson and Turner, 1994). During high tide, many species of fish are found within the flooded marsh (Peterson and Turner, 1994). This area is not accessible to bottlenose dolphins; thus, there may be less prey available to dolphins during high tide. If this were true during low

tide, dolphins may have a greater variety and density of prey. According to optimal foraging theory, predators will specialize in foraging in environments where prey are abundant. This may explain how there are several different foraging behaviors correlated with low tide in Georgia. Further research could test for specializations in foraging behavior by investigating if catalogued dolphins near Savannah are observed having a single foraging behavior over time and compare fish density between high and low tide.

Different behaviors that were correlated with low tide often occurred within the same sightings, and the 4 behaviors with human interaction often occurred within the same sighting. Kerplunks were the most common behavior in terms of occurring with other foraging behaviors. In Shark Bay, Australia, kerplunks were often associated with bottom grubbing, a behavior similar to headstands and hard stops (Connor et al., 2000a). In this study, 3 and 2 sightings with hard stops and headstands, respectively, also had kerplunks (Table 3.4). Sightings with kerplunking near Savannah, Georgia were most commonly associated with mudbank whacking (Table 3.4). Connor et al. (2000a) hypothesized that kerplunks were used to identify the location of fish along shallow sand flats, followed by bottom grubbing when the fish were caught. In Georgia, kerplunks may be used to alert other dolphins of a fish location, but instead of bottom grubbing, dolphins utilize the topography of the creek bank to capture prey in mudbank whacking.

Strand feeding was correlated with small creek size, which is logical considering the benefits of less water volume for herding fish onto a mudbank. Strand feeding behavior was also correlated with low tides like Hoese (1971) and Petricig (1995) reported; however, this behavior occurred more frequently after low tide when saltwater begins to flood back into the estuary. This is also true for beach hunting in Shark Bay,

Australia (Sargeant et al., 2005). In beach hunting, one dolphin will surge fully or partially out of the water as it chases a single fish on a shallow beach (Sargeant et al., 2005). Sargeant et al. (2005) speculated that beach hunting in Australia occurred more frequently after low tide, because it would reduce the risk of the dolphin permanently remaining stranded. The majority of fish photographed during strand feeding events in Georgia were identified as a species of mullet. Juvenile and adult mullet are associated with higher salinities and move upstream with flood tides (Major, 1978; Almeida, 1996). Prey movement may be another explanation why strand feeding occurs more frequently after low tide.

Near Savannah, Georgia, dolphins typically strand fed in groups; however, there were strand feeding events with only 1 dolphin. In South Carolina, the most frequent strand feeding group size was 4 dolphins on the mudbank at 49% (Duffy-Echievarria et al., 2008). Solitary dolphins that were observed strand feeding in South Carolina had a frequency of 3%, and 2 dolphins had a frequency of 5% (Duffy-Echievarria et al., 2008). In this study, the group size most frequently observed strand feeding was 2. Dolphins strand feeding in Georgia may have different optimal group sizes than dolphins strand feeding in other areas. In Georgia, dolphins may gain more energy per unit of time spent strand feeding in smaller groups than in larger groups. Reasons for this are unknown at this time; however, reduced prey availability or reduced number of dolphins that specialize in strand feeding could be likely factors. Eleven catalogued individuals were observed strand feeding near Savannah, Georgia. This number was lower than a study on strand feeding in South Carolina, where 27 out of 45 photographed dolphins in the area were observed strand feeding (Duffy-Echievarria et al., 2008). Strand feeding near

Savannah, Georgia may be a specialized foraging behavior used by only a few of the resident dolphins. Beach hunting in Australia is also considered a specialized foraging behavior as only 4 dolphins and their offspring have been observed beach hunting during a 10 year study (Sargeant et al., 2005).

Two measures have been identified to protect bottlenose dolphins near Savannah, Georgia: 1) limiting human interactions and 2) conserving the estuary. Bottlenose dolphins near Savannah, Georgia are frequently observed foraging in association with human activities (begging, shrimp scavenging, crab pot interactions, and provisioning). This causes concern for the social and physical health of the population (Wells and Scott, 1994; Samuels and Bejder, 2004; Wells et al., 2008; Powell and Wells, 2011). Human factors associated with the high rate of begging should be further investigated to develop plans to reduce future interactions. The estuary habitat along the Georgia coast is very important to resident bottlenose dolphins in terms of supporting prey abundance and foraging resources. The salt marsh environment is important for a variety of prey species (de la Cruz, 1973; Boesch and Turner, 1984). In addition, the structure of salt marshes, tidal creeks, rivers and sounds are important for many of the foraging behaviors observed in this area. For example, bottlenose dolphins in Georgia often use the mudbanks for strand feeding and mudbank whacking.

In conclusion, foraging behaviors of dolphins near Savannah, Georgia have been described for the first time and correlations of some of those behaviors with salinity, temperature, depth, small creeks, and tidal cycle have been identified. How dolphins utilize the salt marsh topography and tidal cycles in terms of foraging have now been identified. This thesis has provided a starting point for future research on foraging

ecology of bottlenose dolphins near Savannah, Georgia. The foraging behaviors described here are a foraging ethogram for future focal follows on dolphins to compare activity budgets. There have been other studies that have reported small-scale spatial partitioning of dolphins in the same bay with different foraging behaviors (Chilvers and Corkeron, 2001; Torres and Read, 2009). This partitioning could be occurring in Georgia as sightings with human interaction foraging behaviors often occur together. Further research on foraging behavior of dolphins in this area could also incorporate fish abundance and distribution or fine scale habitat modeling with bottom topography and water flow.

Table 3.1. Sample collection for bottlenose dolphin *Tursiops truncatus* sightings, foraging events, and strand feeding. Rivers, creeks, and sounds were surveyed near Savannah, Georgia from April to August 2009.

Sightings	Foraging Events	Strand Feeding Events
Location	Location	Location
Time	Time	Time
Group Size	Photographs	Creek Width (m)
Activity		Number of Dolphins
Depth (m)		Photographs
Water Temperature (°C)		
Salinity (ppt)		
Creek Width (m)		
Photographs		

Table 3.2. Time intervals were used to separate minutes of effort searching for and following bottlenose dolphins *Tursiops truncatus* in regards to low tide near Savannah, Georiga. Time intervals were 1 hour each, and a negative interval indicated the effort/follow was before low tide, whereas a positive interval indicated the effort/follow was after low tide.

Hour Interval	Minutes before/after low tide
-6	359-300 min before
-5	299-240 min before
-4	239-180 min before
-3	179-120 min before
-2	119-60 min before
-1	59-0 min before
1	0-59 min after
2	60-119 min after
3	120-179 min after
4	180-239 min after
5	240-299 min after
6	300-359 min after
7	360-419 min after

Table 3.3. The occurrence of foraging behaviors of bottlenose dolphins *Tursiops truncatus* observed near Savannah, Georgia from April to August 2009. Behaviors are organized by the number of sightings the behavior occurred, the number of times the behavior was observed, the number of sightings the behaivor was observed within the first 5 minutes, and the number of times the behavior occurred within the first 5 minutes of the sighting. Only the first column of data are available for deep diving, because the number and time of deep diving events within dolphin sightings were not collected.

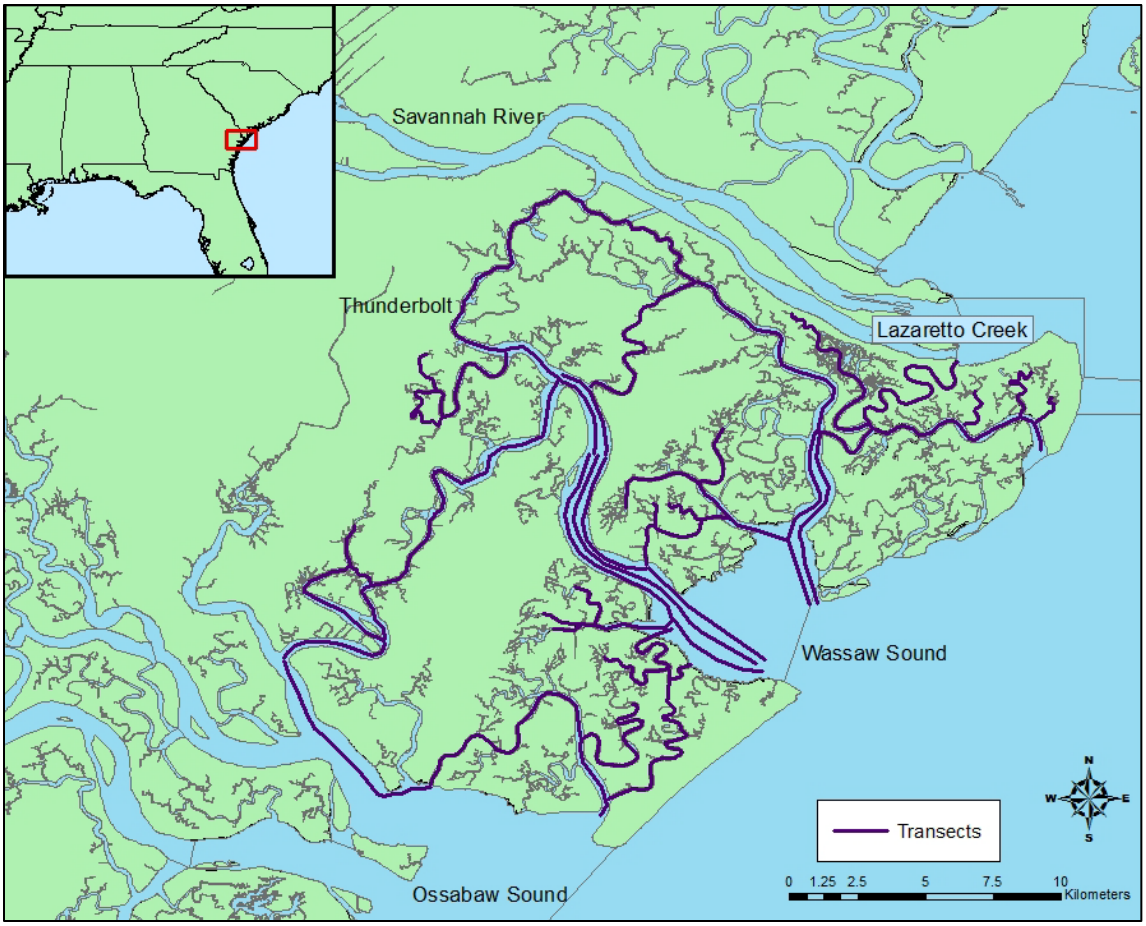
Foraging Behavior	Total number of sightings with behavior	Total number of events	Sightings with behavior within first 5 min	Number of events within first 5 min
Deep Diving	58	---	---	---
Begging	53	146	35	54
Mudbank Whacking	20	44	5	5
Kerplunk	12	24	5	6
Hard Stop	10	28	2	2
Chase	10	28	3	4
Strand Feeding	7	131	3	3
Herding/Circling	7	9	1	1
Headstand	7	18	2	2
Crab Pot	4	7	3	3
Shirmp Scavenge	4	7	3	3
Provisioning	3	5	1	1
Leap Kerplunk	2	11	1	3
Total	197	458	64	87

Table 3.4. The number of sightings with bottlenose dolphins *Tursiops truncatus* during which foraging behaviors observed within the same sighting.

	Strand Feeding	Mudbank Whack	Herding/circling	Kerplunk	Hard Stop	Headstand	Chase	Leap Kerplunk	Deep Diving	Crab Pot	Provisioning	Scavenge Shrimp	Beg
Strand Feeding	---	4	3	1	1		2						3
Mudbank Whack	4	---	5	7	5	4	5		3				5
Herding/Circling	3	5	---	1	2	3	3						3
Kerplunk	1	7	1	---	3	2	3	1	2	1			3
Hard Stop	1	5	2	3	---	2	3		2				
Headstand		4	3	2	2	---	3		1				
Chase	2	5	3	3	3	3	---		1				
Leap Kerplunk				1				---					
Deep Diving		3		2	2	1	1		---				8
Crab Pot				1						---			4
Provisioning											---	2	3
Scavenge Shrimp											2	---	4
Beg	3	5	3	3					8	4	3	4	---

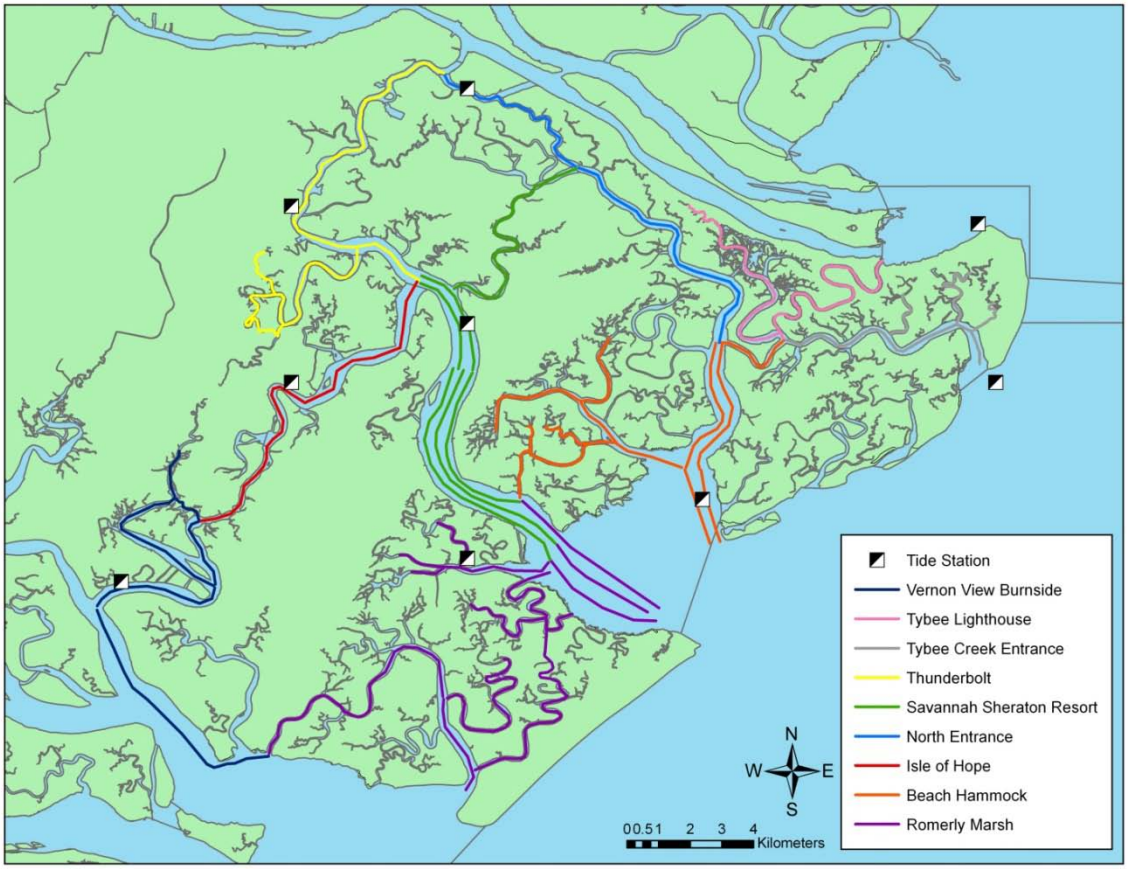
Table 3.5. The number of bottlenose dolphins *Tursiops truncatus* strand feeding near Savannah, Georgia during surveys from April 2009 to August 2009. Total number of events are based on strand feeding events where the groups size was known and confirmed by photos.

	Date of Strand Feeding							
Group Size	6/6/2009	6/20/2009	6/21/2009	6/23/2009	7/1/2009	7/5/2009	8/1/2009	Total Events
1	0	1	0	0	0	2	0	3
2	1	1	1	2	63	7	2	77
3	5	15	0	0	0	0	23	43
4	5	0	0	0	0	0	2	7
Total Events	11	17	1	2	63	9	27	130



Created by SRB 1/24/2011 Projection: Georgia Stateplane East (FIPS 1001)
Data Source: ESRI state layer and USGS National Hydrography Dataset

Figure 3.1. Planned survey transects of the rivers, creeks, and sounds near Savannah, Georgia from April to August 2009.



Created by SRB 12/01/2010 Projection: Georgia Stateplane East (FIPS 1001)
Data Source: ESRI state layer, USGS National Hydrography Dataset, and NOAA

Figure 3.2. Map of survey transects and NOAA Tidal Stations. Transects were grouped with names corresponding to the nearest tidal station. Tide information for effort, bottlenose dolphin *Tursiops truncatus* follows, sightings, and foraging events within the transect group were determined using the matching 2009 NOAA tide station. Rivers, creeks, and sounds were surveyed near Savannah, Georgia from April to August 2009.

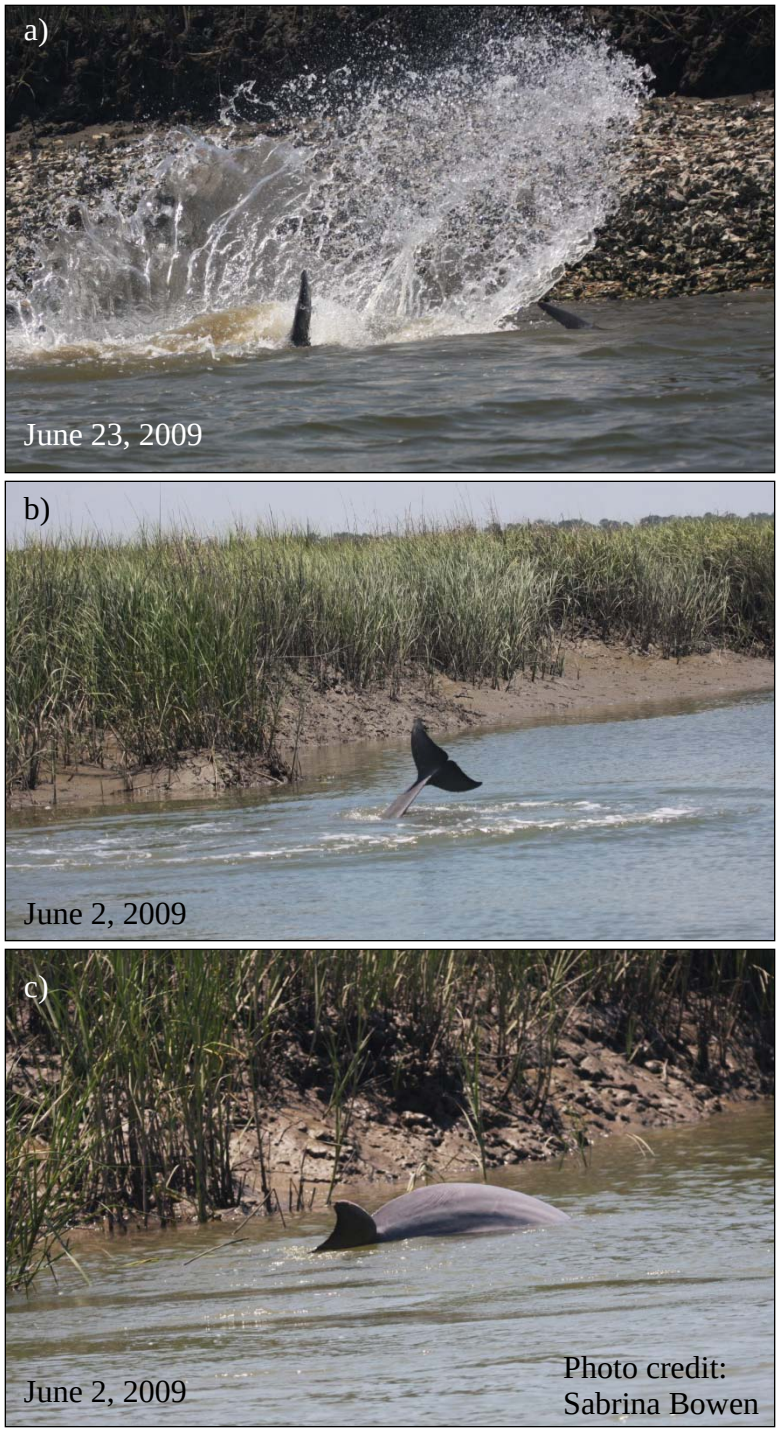


Figure 3.3. Photographs of a) mudbank whacking, b) headstand, and c) hard stop foraging behaviors of bottlenose dolphin *Tursiops truncatus* collected near Savannah, GA. Photographs were collected in accordance with the Marine Mammal Protection Act under NMFS Letter of Confirmation # 14219.

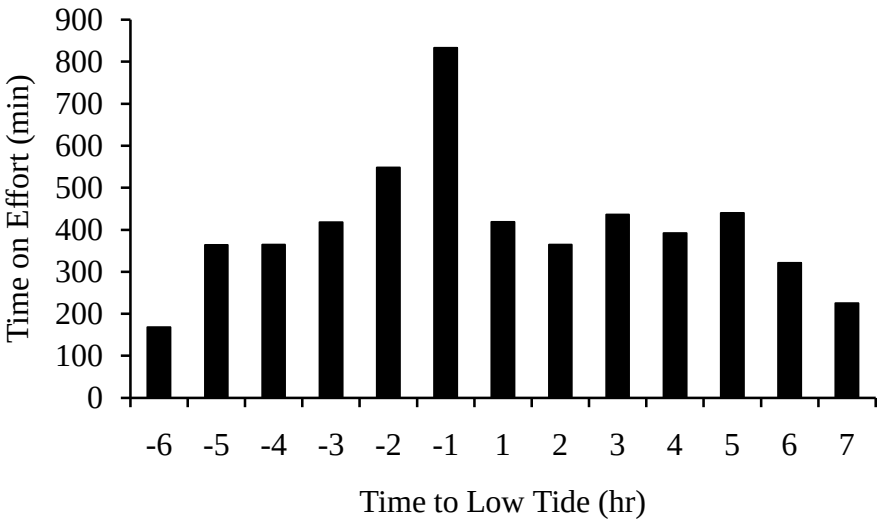


Figure 3.4. Total minutes spent on effort searching for bottlenose dolphins *Tursiops truncatus* distributed by hour intervals before and after low tide. Negative numbers indicate hours before low tide (ebb tide) whereas positive numbers are hours after low tide (flood tide). Surveys were conducted from April 2009 to August 2009 in the inshore waterways near Savannah, Georgia.

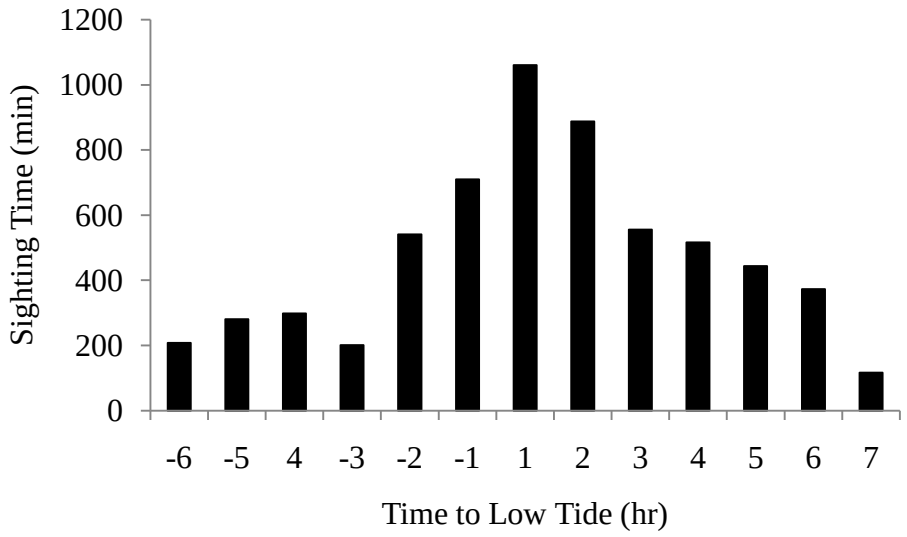


Figure 3.5. Total minutes spent following bottlenose dolphins *Tursiops truncatus* during sightings distributed by hour intervals before and after low tide. Negative numbers indicate hours before low tide (ebb tide) whereas positive numbers are hours after low tide (flood tide). Surveys were conducted from April 2009 to August 2009 in the inshore waterways near Savannah, Georgia.

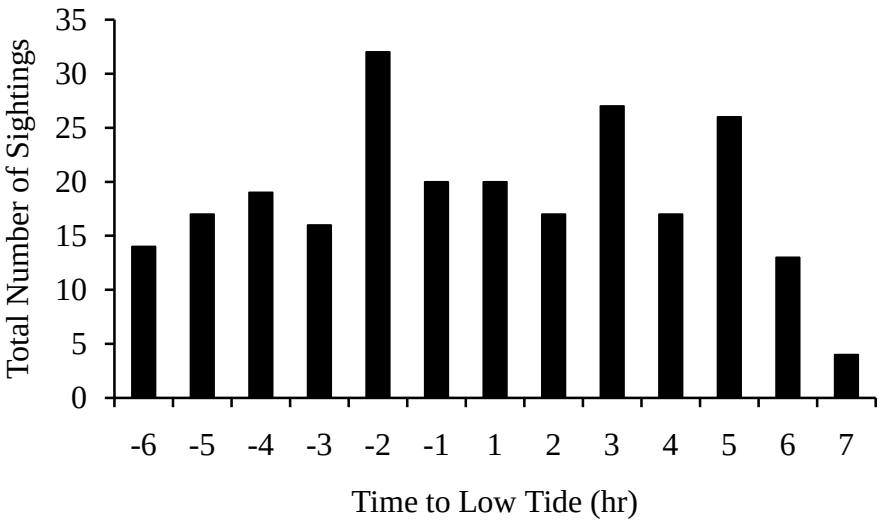


Figure 3.6. Total number of bottlenose dolphin *Tursiops truncatus* sightings during surveys near Savannah, Georgia from April 2009 to August 2009. Sightings are distributed by hour intervals before or after low tide. Negative numbers indicate hours before low tide (ebb tide), whereas positive numbers are hours after low tide (flood tide).

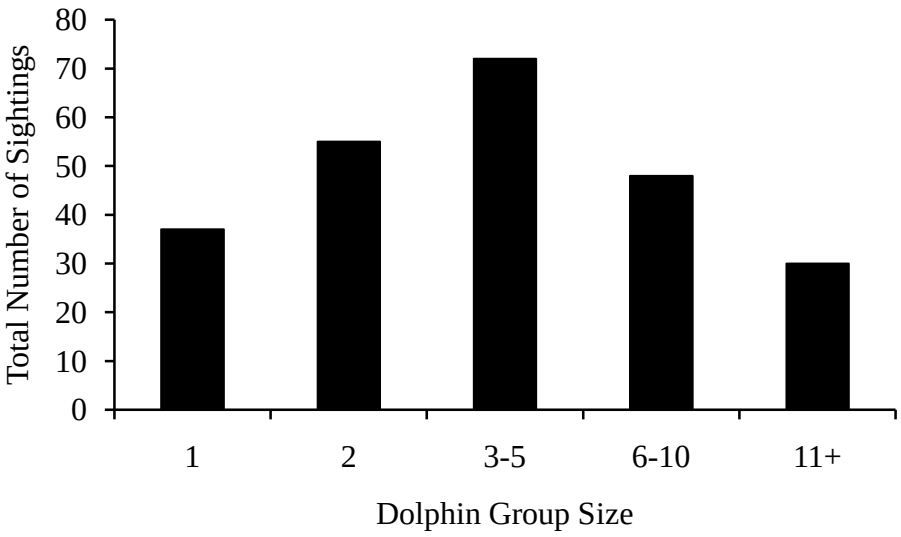


Figure 3.7. Total number of bottlenose dolphin *Tursiops truncatus* sightings during surveys near Savannah, Georgia from April 2009 to August 2009. Sightings are distributed by the best estimated number of dolphins in the sighting.

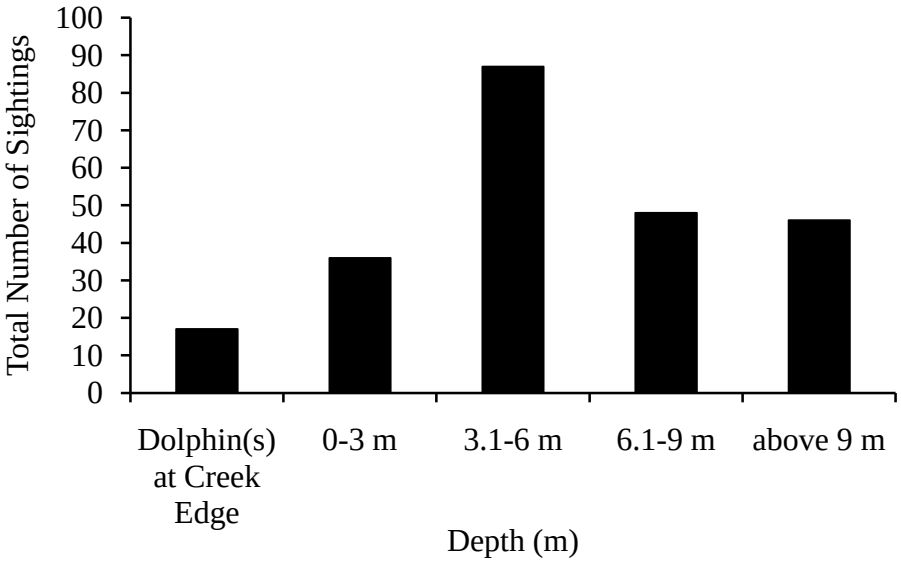


Figure 3.8. Total number of bottlenose dolphin *Tursiops truncatus* sightings during surveys near Savannah, Georgia from April 2009 to August 2009. Sightings are distributed by water depth category. Sightings where dolphins were at the creek edge do not have depth values since the water depth at the creek edge could not be collected from the vessel.

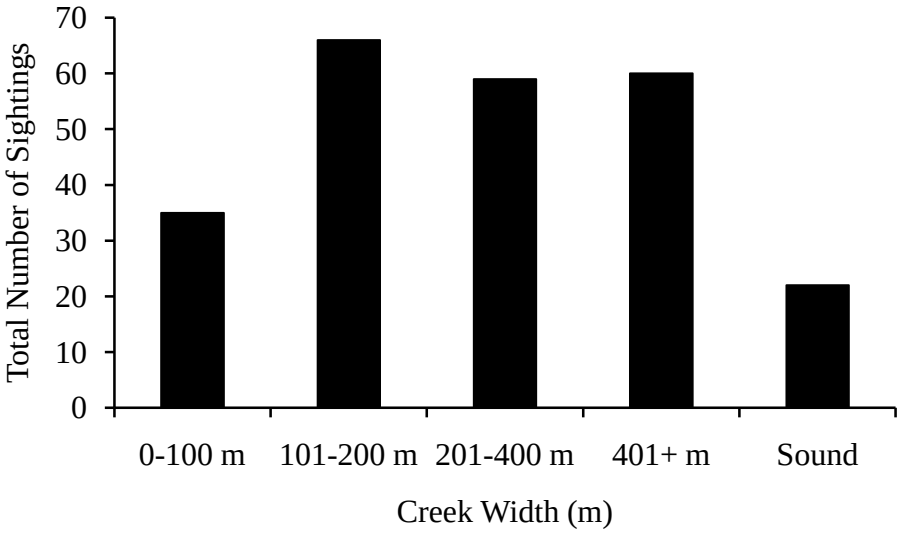
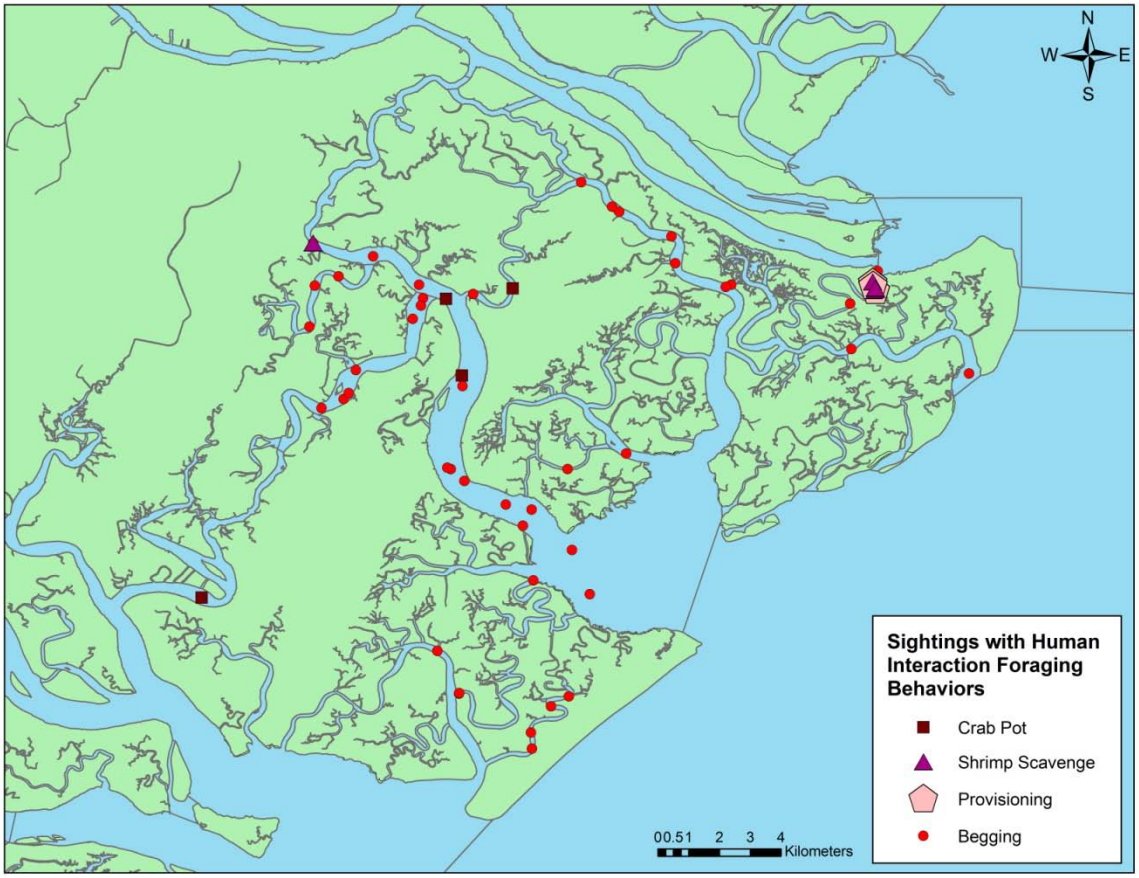
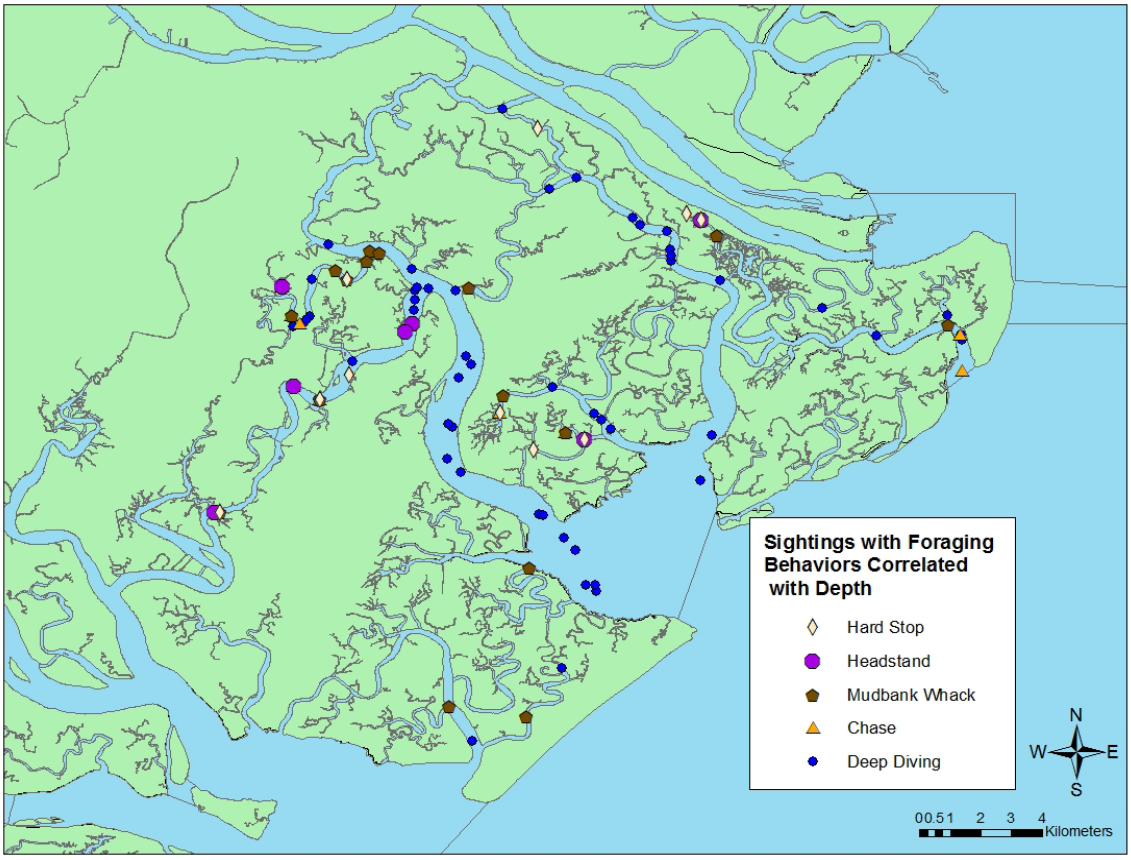


Figure 3.9. Total number of bottlenose dolphin *Tursiops truncatus* sightings during surveys near Savannah, Georgia from April 2009 to August 2009. Sightings are distributed by creek width except for sighting inside Wassaw Sound, which was too wide to determine creek widths.



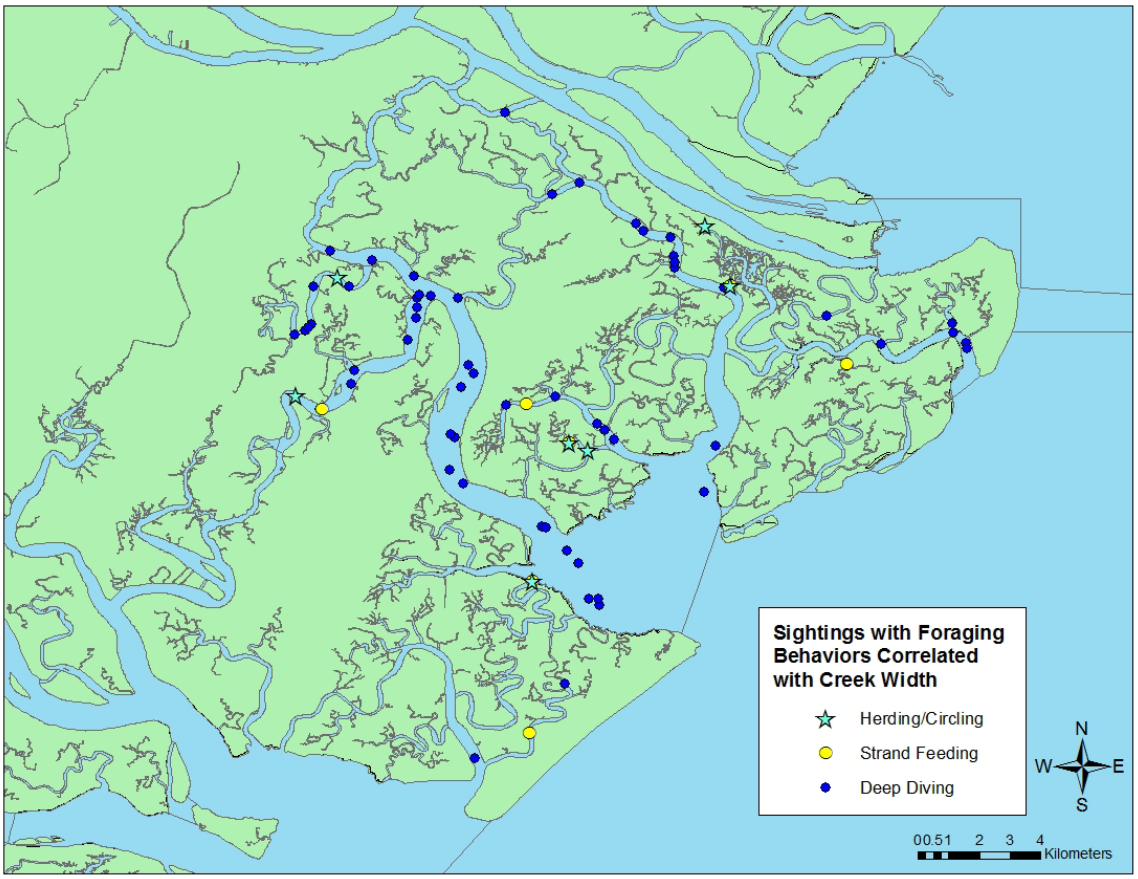
Created by SRB 1/20/2011 Projection: Georgia Stateplane East (FIPS 1001)
Data Source: ESRI state layer and USGS National Hydrography Dataset

Figure 3.10. Location of bottlenose dolphin *Tursiops truncatus* sightings with foraging behaviors that involved human interaction (crap pots, shrimp scavenging, provisioning, and begging) near Savannah, Georgia from April to August 2009.



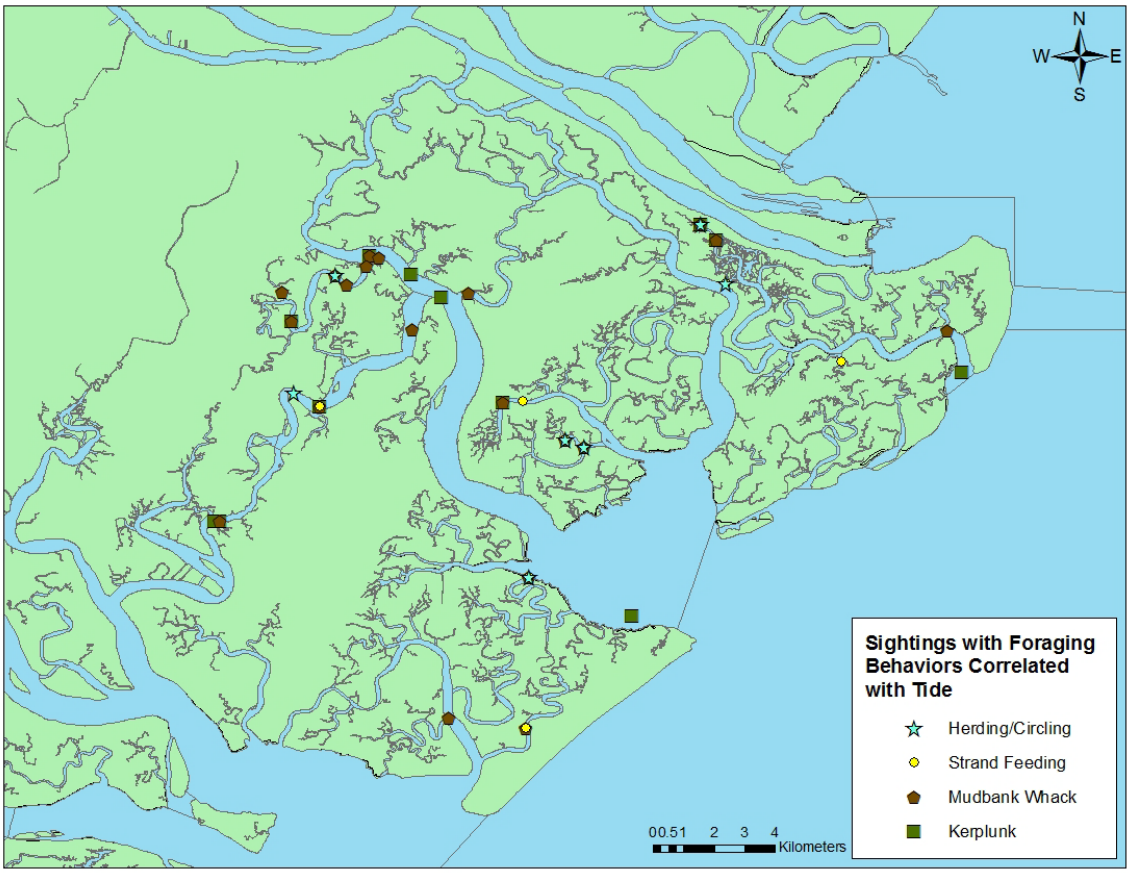
Created by SRB 1/20/2011 Projection: Georgia Stateplane East (FIPS 1001)
Data Source: ESRI state layer and USGS National Hydrography Dataset

Figure 3.11. Locations of bottlenose dolphin *Tursiops truncatus* sightings with foraging behaviors that were correlated with water depths near Savannah, Georgia from April to August 2009.



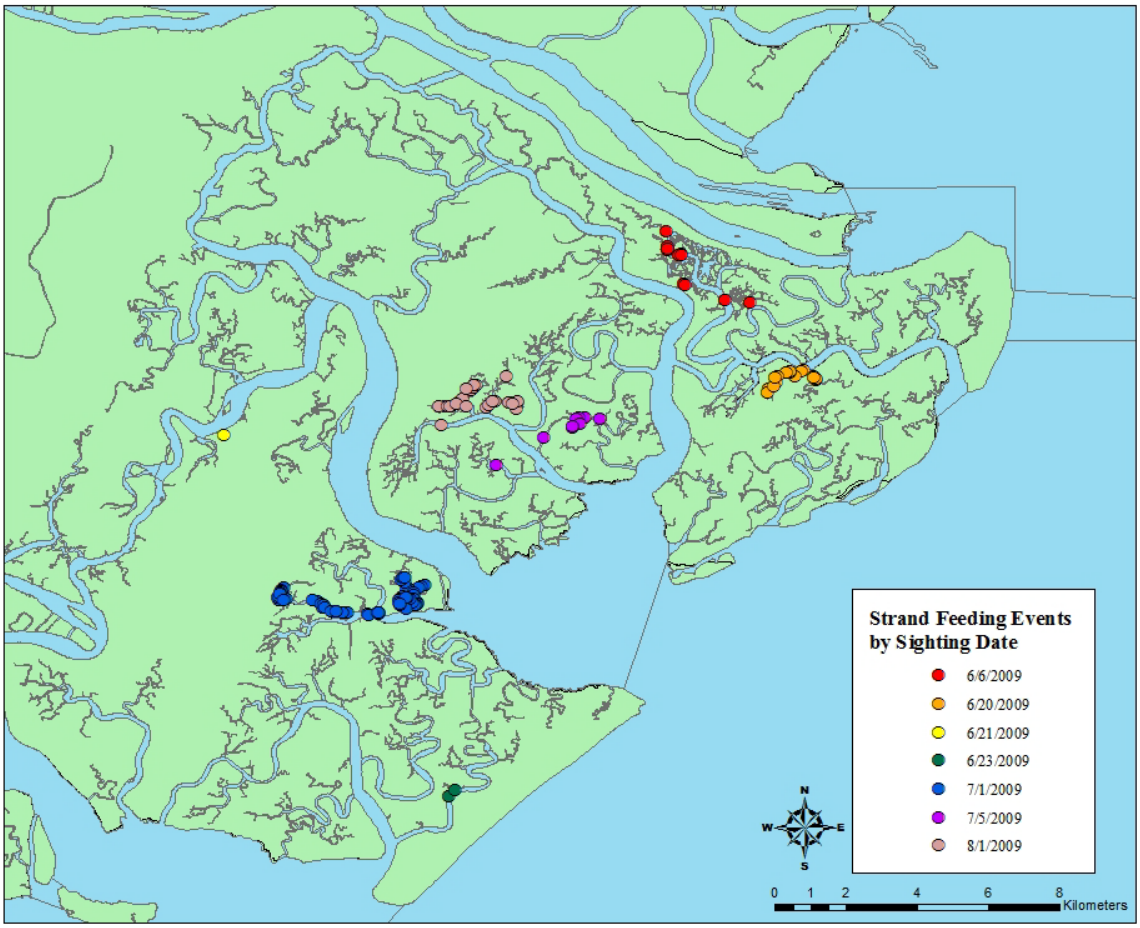
Created by SRB 1/20/2011 Projection: Georgia Stateplane East (FIPS 1001)
Data Source: ESRI state layer and USGS National Hydrography Dataset

Figure 3.12. Locations of bottlenose dolphin *Tursiops truncatus* sightings with foraging behaviors that were correlated with creek width near Savannah, Georgia from April to August 2009.



Created by SRB 1/20/2011 Projection: Georgia Stateplane East (FIPS 1001)
Data Source: ESRI state layer and USGS National Hydrography Dataset

Figure 3.13. Locations of bottlenose dolphin *Tursiops truncatus* sightings with foraging events that were correlated with time to low tide. Waterways near Savannah, Georgia were surveyed from April to August 2009.



Created by SRB 1/24/2011 Projection: Georgia Stateplane East (FIPS 1001)
Data Source: ESRI state layer and USGS National Hydrography Dataset

Figure 3.14. Locations of bottlenose dolphin *Tursiops truncatus* strand feeding events separated by date sighting was observed near Savannah, Georgia from April to August 2009.

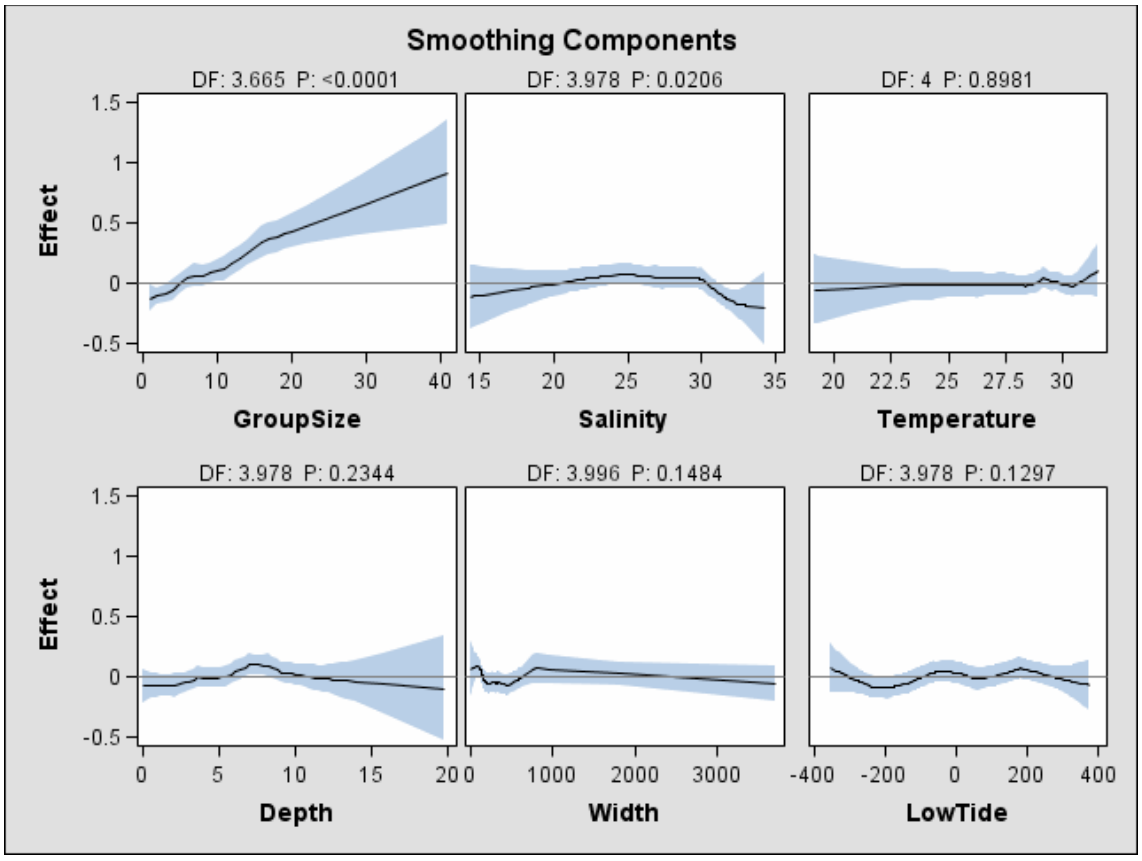


Figure 3.15. Multivariate GAM smoothing functions with 95% confidence bands of predictor variables for the presence/absence of begging behavior during sightings of bottlenose dolphins *Tursiops truncatus* near Savannah, Georgia. Degrees of freedom and p-values are presented at the top of each graph. The level of positive and negative effect of the variables is on the y-axis.

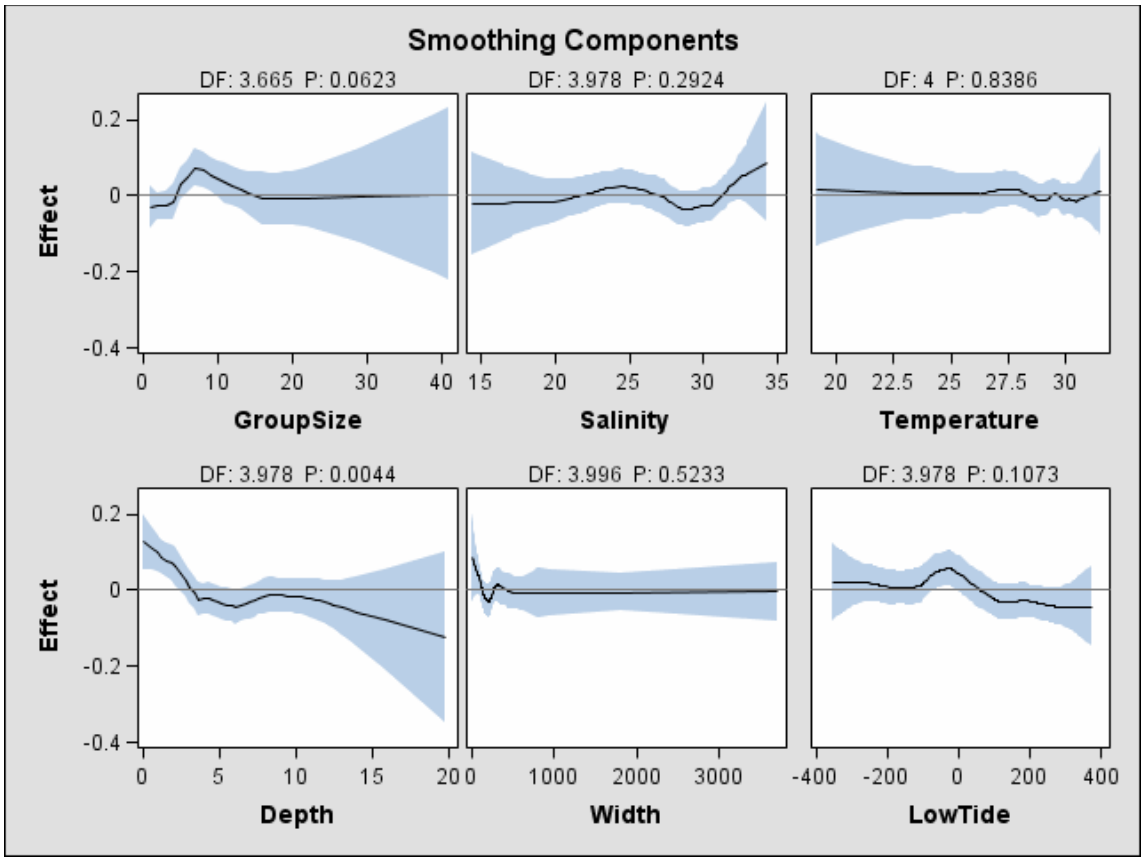


Figure 3.16. Multivariate GAM smoothing functions with 95% confidence bands of predictor variables for the presence/absence of chasing behavior during sightings of bottlenose dolphins *Tursiops truncatus* near Savannah, Georgia. Degrees of freedom and p-values are presented at the top of each graph. The level of positive and negative effect of the variables is on the y-axis.

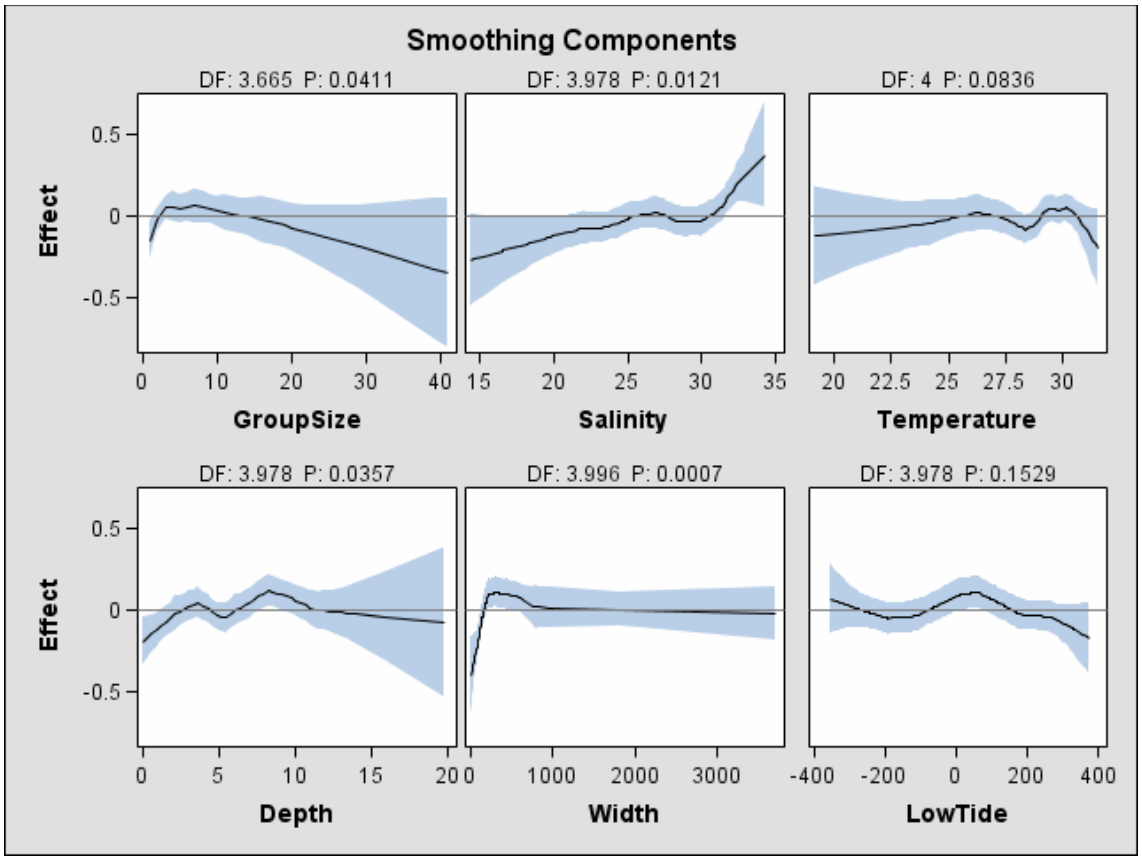


Figure 3.17. Multivariate GAM smoothing functions with 95% confidence bands of predictor variables for the presence/absence of deep diving behavior during sightings of bottlenose dolphins *Tursiops truncatus* near Savannah, Georgia. Degrees of freedom and p-values are presented at the top of each graph. The level of positive and negative effect of the variables is on the y-axis.

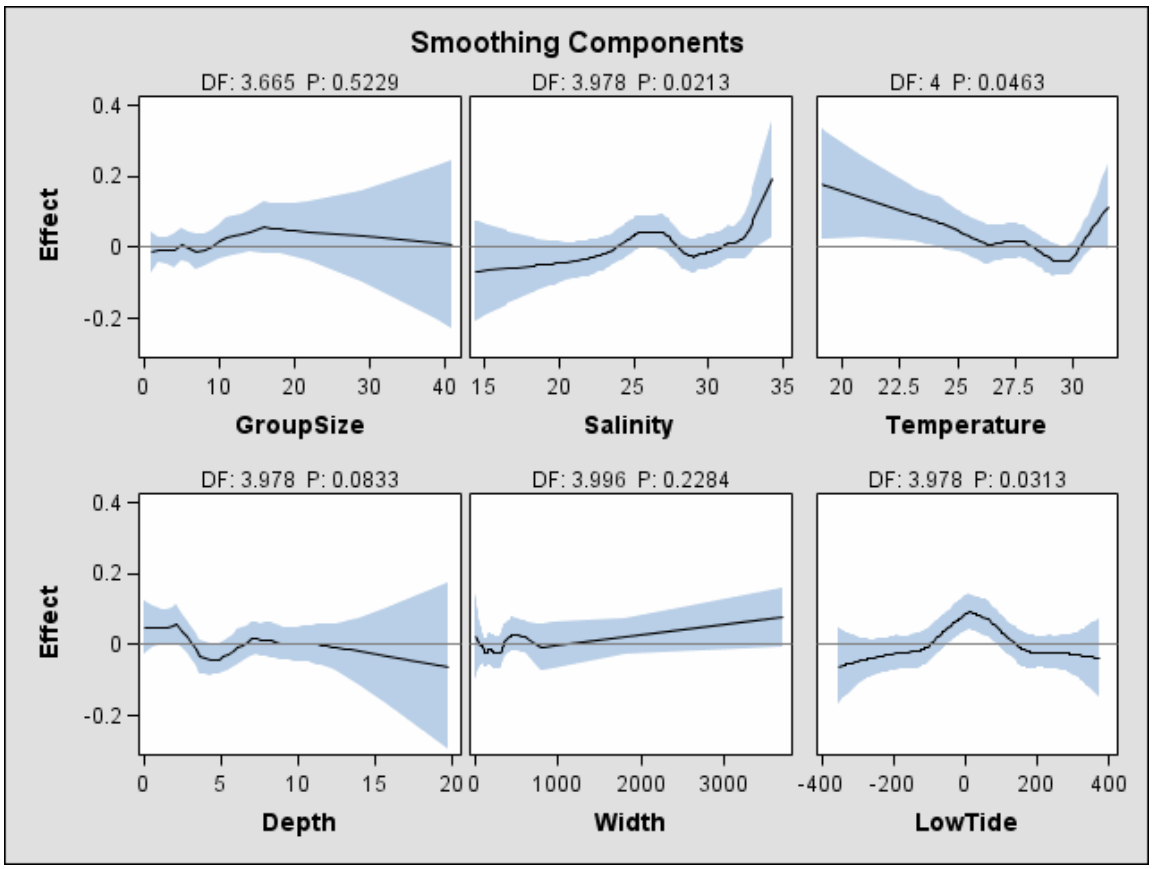


Figure 3.18. Multivariate GAM smoothing functions with 95% confidence bands of predictor variables for the presence/absence of kerplunks behavior during sightings of bottlenose dolphins *Tursiops truncatus* near Savannah, Georgia. Degrees of freedom and p-values are presented at the top of each graph. The level of positive and negative effect of the variables is on the y-axis.

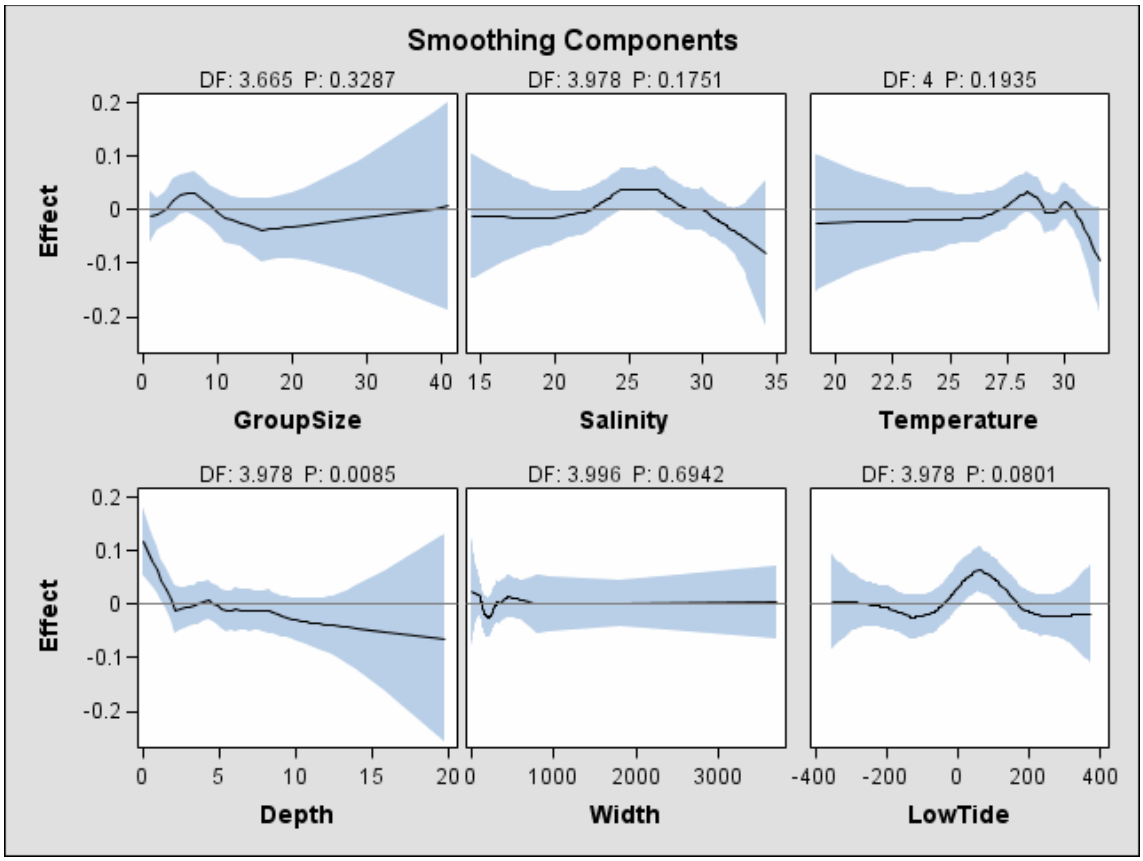


Figure 3.19. Multivariate GAM smoothing functions with 95% confidence bands of predictor variables for the presence/absence of headstand behavior during sightings of bottlenose dolphins *Tursiops truncatus* near Savannah, Georgia. Degrees of freedom and p-values are presented at the top of each graph. The level of positive and negative effect of the variables is on the y-axis.

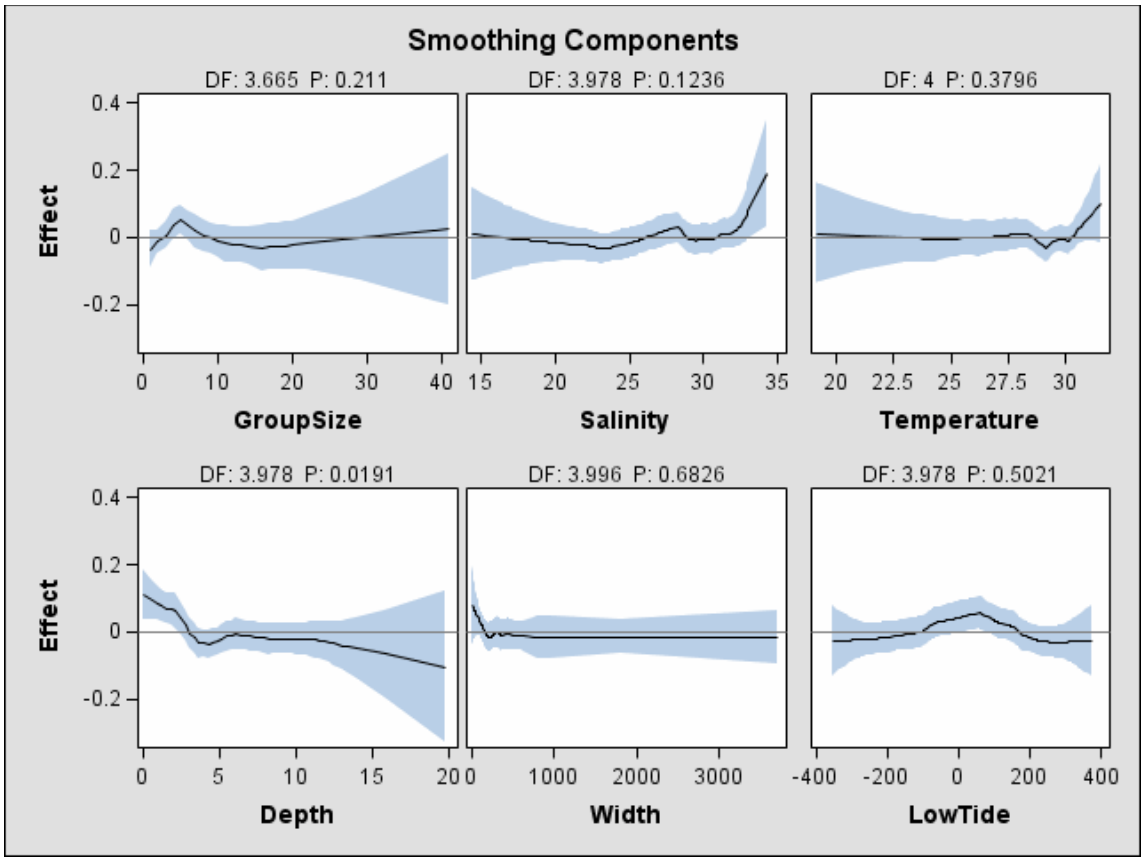


Figure 3.20. Multivariate GAM smoothing functions with 95% confidence bands of predictor variables for the presence/absence of hard stop behavior during sightings of bottlenose dolphins *Tursiops truncatus* near Savannah, Georgia. Degrees of freedom and p-values are presented at the top of each graph. The level of positive and negative effect of the variables is on the y-axis.

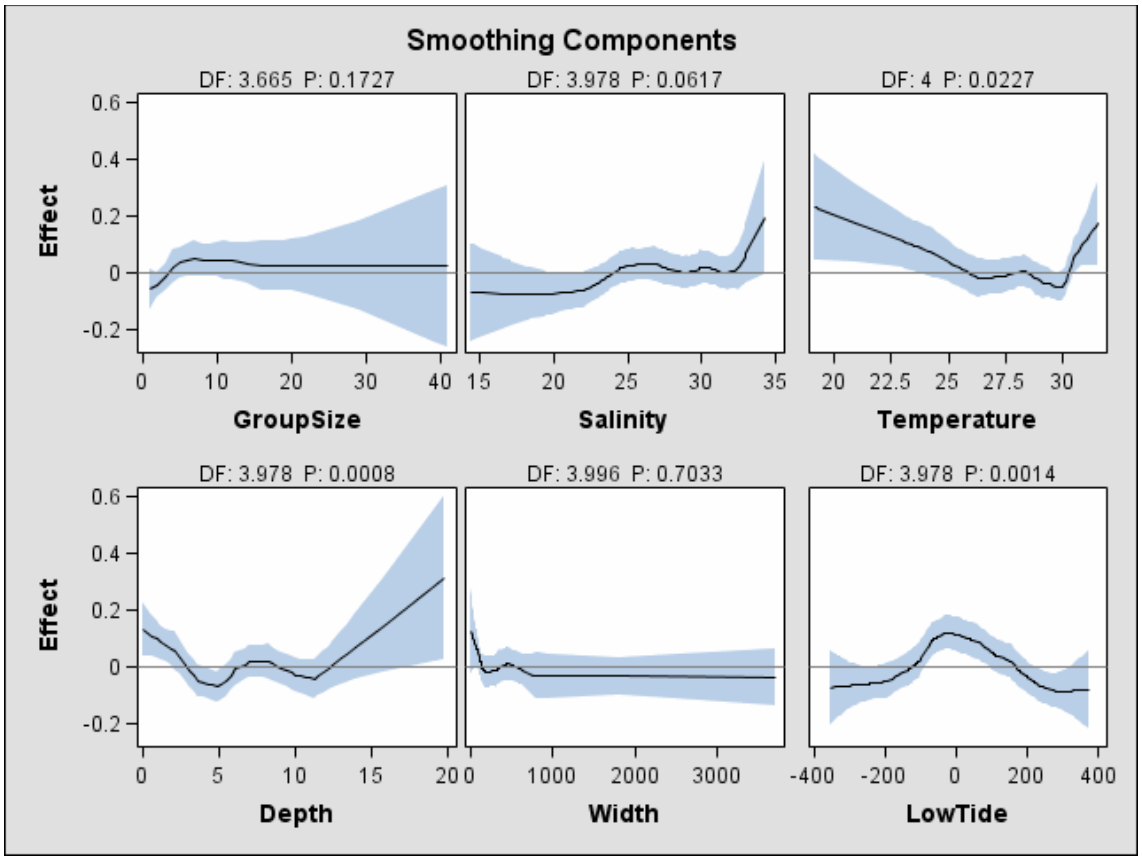


Figure 3.21. Multivariate GAM smoothing functions with 95% confidence bands of predictor variables for the presence/absence of mudbank whack behavior during sightings of bottlenose dolphins *Tursiops truncatus* near Savannah, Georgia. Degrees of freedom and p-values are presented at the top of each graph. The level of positive and negative effect of the variables is on the y-axis.

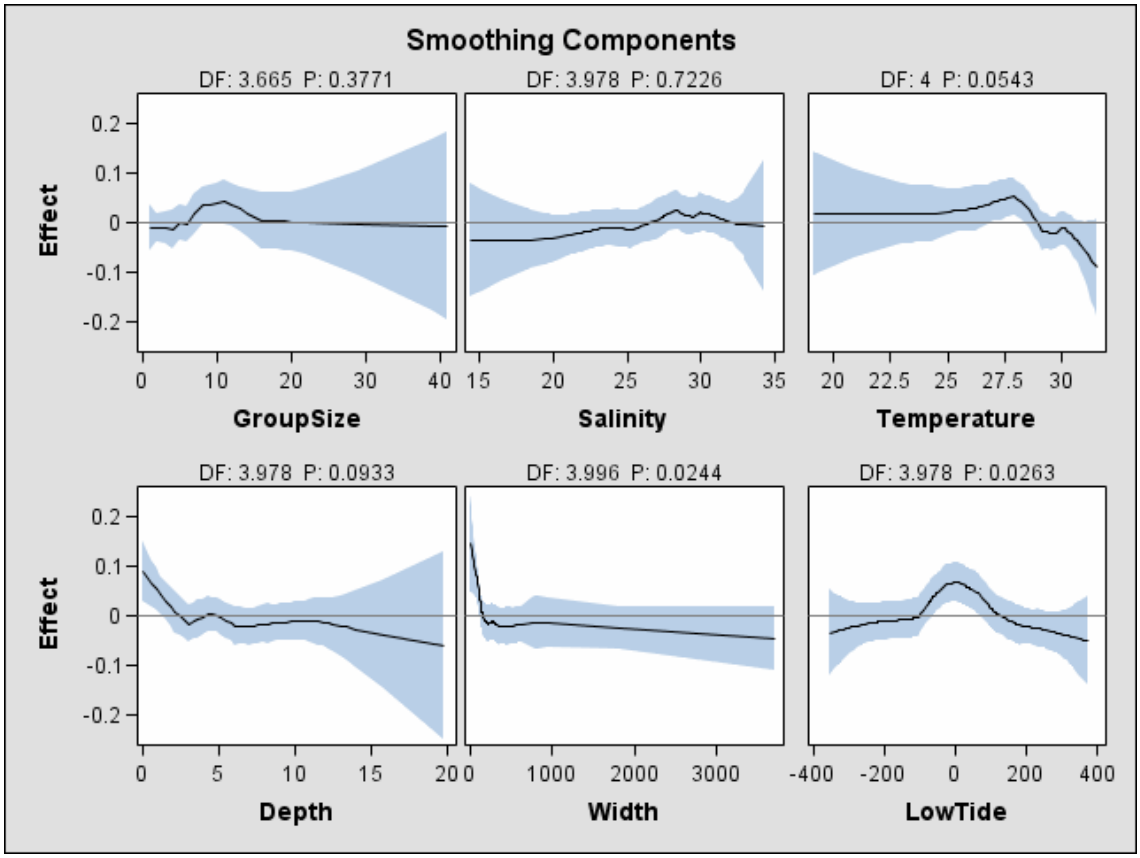


Figure 3.22. Multivariate GAM smoothing functions with 95% confidence bands of predictor variables for the presence/absence of herding/circling behavior during sightings of bottlenose dolphins *Tursiops truncatus* near Savannah, Georgia. Degrees of freedom and p-values are presented at the top of each graph. The level of positive and negative effect of the variables is on the y-axis.

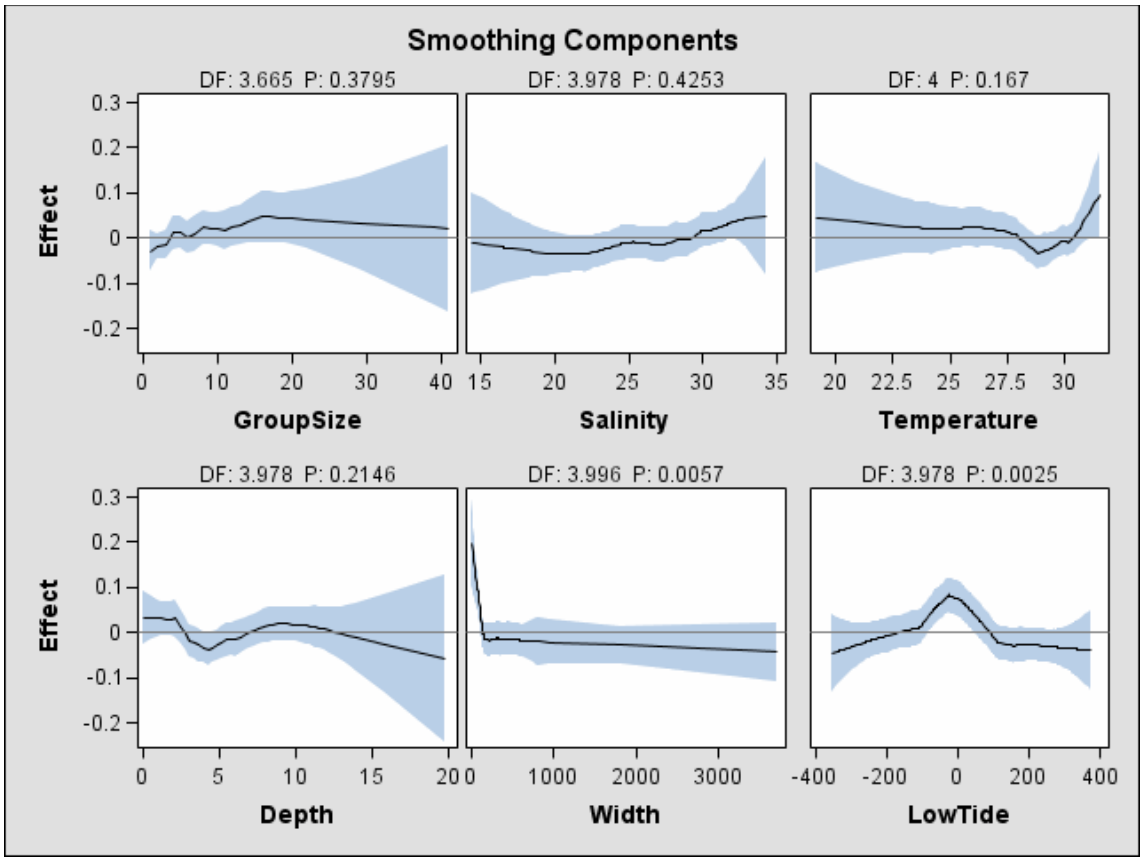


Figure 3.23. Multivariate GAM smoothing functions with 95% confidence bands of predictor variables for the presence/absence of strand feeding during sightings of bottlenose dolphins *Tursiops truncatus* near Savannah, Georgia. Degrees of freedom and p-values are presented at the top of each graph. The level of positive and negative effect of the variables is on the y-axis.

CHAPTER 4

Synthesis

Before this study, little was known about the foraging ecology of bottlenose dolphin *Tursiops truncatus* in the Northwest Florida Panhandle and estuaries between the Savannah River and Ossabaw sound in Georgia. Sciaenidae were determined to be the most important prey of bottlenose dolphin in the Northwest Florida Panhandle. Prey from the family Sciaenidae likely provide the greatest energy gain per unit of time foraging due to the high frequency, abundance, and proportion of reconstructed weight found from stomachs collected from the Northwest Florida Panhandle. It has also been determined that diet of dolphins that stranded in the absence of a *Karenia brevis* bloom are different from diet of dolphins that stranded during and shortly after the bloom. This information is useful for previous and future Unusual Mortality Event (UME) investigations. The foraging behavior was studied for dolphins near Savannah, Georgia instead of diet. Foraging behaviors of dolphins near Savannah, Georgia have been classified and correlations among some behaviors to dolphin group size and environmental variables have been discovered. Dolphins near Savannah, Georgia utilize small creeks with shallow depths at low tide which may increase foraging efficiency. Environmental variables and group size of strand feeding behavior by dolphin from Savannah, GA have been investigated and compared to results of other studies on strand feeding. Due to differences in the purpose and analysis of each study, the diet and foraging behaviors of dolphins from Northwest Florida Panhandle and Savannah,

Georgia cannot be compared. However, future studies on foraging ecology in these areas would allow such comparisons.

Spot *Leiostomus xanthurus*, squid family Loliginidae, pinfish *Lagodon rhomboides*, Atlantic croaker *Micropogonias undulatus*, and silver perch *Bairdiella chrysoura* are the most important prey species of bottlenose dolphins in the Northwest Florida Panhandle. Dolphins that stranded during and shortly after the *K. brevis* bloom were found to have different diets from dolphins that stranded in the absence of the bloom. Squid have a higher frequency of occurrence and abundance in non-bloom stomachs than bloom stomachs. Squid, however, are equal in bay and coast stomachs, suggesting this difference could be due to the *K. brevis* bloom. Long-term sampling and analysis of stomachs collected from dolphins should continue to determine if the differences in diet observed in this study persist over time. An alternative hypothesis that dolphins consumed more demersal prey and not Clupeidae as previously was presented. However, due to differences in UME events, incomplete analysis, and differences in *K. brevis* bloom distribution, additional analysis are needed. In addition, this study will be helpful to investigate the impact of the 2010 Deepwater Horizon Oil Spill in the Gulf of Mexico on bottlenose dolphins in the Northern Gulf of Mexico as no other studies on diet of dolphins in this area have been published.

The diet of dolphins in Georgia could not be determined at this time because there were not enough stomach samples. Instead, the foraging behaviors of dolphin in this area were studied. Many of the foraging behaviors observed near Savannah, Georgia have been observed in other areas throughout the world (Hoese, 1971; Leatherwood, 1975; Rigley et al., 1981; Nowacek, 1999; Connor et al., 2000a; Noke and Odell, 2002;

Samuels and Bejder, 2004; Cunningham-Smith et al., 2006; Finn et al., 2008). Other behaviors such as leap kerplunking, headstands, and hard stops were similar to other foraging behaviors such as lunging and bottom grubbing/rooting (Leatherwood, 1975; Rossbach and Herzing, 1997; Nowacek, 2002). The behaviors described here provide a foraging ethogram for future studies on foraging behavioral ecology.

Significant correlations among begging and deep diving with group size reported in this study were similar to observations from other studies (Chilvers and Corkeron, 2001; Speakman et al., 2006; Torres and Read, 2009). Kerplunking and deep diving were correlated with salinity, which may relate to prey distribution with salinity. Headstand, hard stops, chasing, mudbank whacking, herding/circling, and strand feeding were associated with shallow water or small creeks. The lower water volume and physical barriers of small creeks could be beneficial dolphins in capturing prey.

Strand feeding occurs more frequently after low tide and differences in strand feeding exists for dolphins near Savannah, Georgia to dolphins in South Carolina. There was 1 occurrence in this study where a single dolphin strand feeding was photographed with a Bothidae in its mouth (Figure 4.1). This event is the first report of strand feeding on non-schooling prey. Strand feeding near Savannah, Georgia occurs in smaller groups than strand feeding in Bluffton, South Carolina. The most frequent number of dolphins on the mudbank in this study was 2; whereas in South Carolina the most frequent number of dolphins on the mudbank was 4 (Duffy-Echievarria et al., 2008). In Georgia, dolphins may gain more energy per unit of time spent strand feeding in smaller groups or alone than in a larger group.

Both studies in the Northwest Florida Panhandle and near Savannah, Georgia provide important background information on foraging ecology. Both studies identify how dolphins foraging on specific prey, utilize foraging behavior, or forage in a area or tidal stage in order to increase energy gained per unit of time spent foraging. Neither of these studies can be compared in terms of diet and foraging behavior, as the purpose and the methodology were different. A study on foraging behavior of dolphins in the Northwest Florida Panhandle, similar to the foraging behavior study in Georgia, should be done to obtain baseline data on foraging behavior. This baseline data could be compared to test whether dolphins changed foraging behaviors and locations following a *K. brevis* bloom. Would dolphins in the Northwest Florida Panhandle increase foraging at the surface on filter feeding prey or would they increase foraging on demersal prey using behaviors such as bottom grubbing or deep diving during a *K. brevis* bloom? Foraging behavior data could also quantify the amount of foraging behavior that is related to human activities such as scavenging from by-catch of shrimp vessels and depredation in the Northwest Florida Panhandle in comparison to other foraging behaviors. Changes in foraging behavior and location may be related to prey distribution, thus combining a behavior foraging study on dolphins with fish abundance surveys should be done. Now that the foraging behaviors near Savannah, Georgia have been identified, the most important prey species should be identified. Dolphins in Georgia have been observed feeding on mullet spp., Bothidae, and by-catch discards from shrimp vessels. These observations were incidental and cannot determine the importance of prey in diet. Prey selection and foraging behavior is important to monitor impacts of environmental changes on bottlenose dolphins and investigate future UMEs.

There have been no UMEs declared for dolphins in Georgia estuaries; however, environmental changes that could affect these animals are occurring. Monitoring along the Skidaway River (a river within the Georgia study site) for 20 years indicated a general increase of phytoplankton and decrease in dissolved oxygen (Verity et al., 2006; Verity and Borkman, 2010). Low levels of oxygen will cause stress and morality of fish (Diaz and Rossenberg, 1995). Decreases in prey populations over time will likely cause a change in dolphin foraging behavior. It is important to monitor this change over time to determine impacts on bottlenose dolphins.

Additional foraging behavioral studies are suggested for the estuaries near Savannah, Georgia. These include the following: assigning foraging behaviors to the various foraging stages; investigating the influence of spring and neap tide on foraging behaviors; and to determine the rate of consumption for individual dolphins that strand feed. The 4 stages of foraging have been described by Stephens and Kerbs (1986) to be search, pursue, capture, and handle. Perhaps mudbank whacking could be classified as a search stage of foraging as the strong wave of produced might "scare" fish (oyster toadfish) out of hiding in the oysters, or other fish along the edge. A study that marks the timing of behaviors for individuals may be able to assign behaviors described in this thesis to stages using similar methodology as Nowacek (2002). This research was unable to investigate correlations of behaviors to spring or neap tides in a few months of survey effort. A study with methodology focusing on even survey effort among spring/neap tides may be able to address additional correlations. Consumption rate on dolphins is difficult to study in the wild but since strand feeding occurs on land, it may be possible to identify species and number of fish consumed. With proper camera placement, the

consumption rate, or number of prey eaten, of strand feeding dolphins may be assessed to determine the efficiency of strand feeding among individual dolphins. These are just a few examples of future research to study foraging ecology on dolphins near Savannah, Georgia.

Further research into foraging ecology in both study areas could be done by alternative methodology. These include prey distribution and abundance, fatty acid signatures, and stable isotope signatures. Do blooms cause the same changes in fish diversity and abundance in the Northwest Florida Panhandle as central Florida? Prey distribution and abundance in the Northwest Florida Panhandle could be a complimentary study to the foraging behavior of dolphins in this area in the presence and absence of a *K. brevis* bloom. Prey distribution and abundance in the estuary near Savannah, Georgia could be used to determine if the same correlations between dolphin behavior and environmental variables are true for prey. In addition, monitoring could determine if changes in prey abundance occur over time and if these changes would alter foraging behavior of dolphins. An archive of stomach samples for analysis can take time and diet interpretations can be biased due to the collection of stomachs from dolphins that may have died through an unknown illness. Blubber for fatty acid analysis and skin for stable isotopes could be collected from live dolphins through biopsy darting. Due to the high prevalence of begging near Savannah, Georgia, dolphins are not wary of boats and thus a full blubber sample may be easier to collect since the animal would be so close to the boat. These samples can be used to determine changes in diet, spatial differences, and may even be able to quantify diet if a prey reference collection is available (Tollit et al., 2010). Stable isotope analysis compares the ratio of isotopes in order to study trophic

interactions and food source (benthic vs. pelagic, marsh vs. offshore). Fatty acids can be used to assess spatial and temporal differences in foraging and diet. Perhaps these could be used to determine and compare the most important prey species of living dolphins from the Northwest Florida Panhandle during a *K. brevis* bloom to living dolphins in the absence of a bloom. Partitioning of dolphins within the same bay by foraging behavior has been observed in other studies (Chilvers and Corkeron, 2001). If such partitioning occurs with resident dolphins near Savannah, Georgia, then fatty acid signatures and stable isotopes might be different for dolphins that foraged in association with human interactions (begging and shrimp scavenging) than dolphins that foraged in small creeks (strand feeding). Commercial shrimp fisheries have open and close seasons of fishing. Stable isotopes and fatty acid signatures maybe used to assess if dolphin diet changes among open and closed fishing seasons.

In conclusion, background information on foraging ecology on dolphins in the Northwest Florida Panhandle and dolphins near Savannah, Georgia has been obtained. Suggestions for future studies on dolphins in these areas have been provided. Future research on dolphins in the Northwest Florida Panhandle include analysis on additional stomachs, completed UME stomach analysis, and foraging behavioral study. Future research on dolphins near Savannah, Georgia include stomach content analysis, classification of foraging stages, affect of spring and neap tides on foraging, and consumption rate of strand feeding dolphins. A common research suggestion for both studies included prey sampling, stable isotope analysis, and fatty acid analysis. Continued foraging ecology studies with different methodology would benefit both areas in understanding previous UMEs and monitor dolphins such future events occur.

Figure 4.1. Photograph of a bottlenose dolphin *Tursiops truncatus* strand feeding with a Bothidae in its mouth taken near Savannah, GA. Photographs were collected in accordance with the Marine Mammal Protection Act under NMFS Letter of Confirmation # 14219.

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